SCIENTIFIC AMERICAN

No. SUPPLEMENT 442

Scientific American Supplement, Vol. XVII., No. 442. Scientific American, established 1845. NEW YORK, JUNE 21, 1884. Scientific American Supplement, $5 a year. Scientific American and Supplement, $7 a year.

NEVEUX'S VACUUM PUMP.

MR. CHARLES G. E. NEVEUX, of the city of New York, has invented a new and improved vacuum pump, of which the following is a description:

Figure 1 is a longitudinal sectional elevation, showing it adjusted to operate in the manner of a Geissler pump, the mercury passing into the bulb. Fig. 2 is a like view, with the mercury passing out of the bulb. Fig. 3 is a like sectional view of the pump, showing it adjusted to operate as a Sprengel pump. Fig. 4 is a cross-sectional elevation of the same on the line *x x*, Fig. 3. Fig. 5 is a sectional plan view of the same on the line *y y*, Fig. 3. Fig. 6 is a sectional plan view of the same on the line *z z*, Fig. 3. The drawings are to a scale of one inch to the foot.

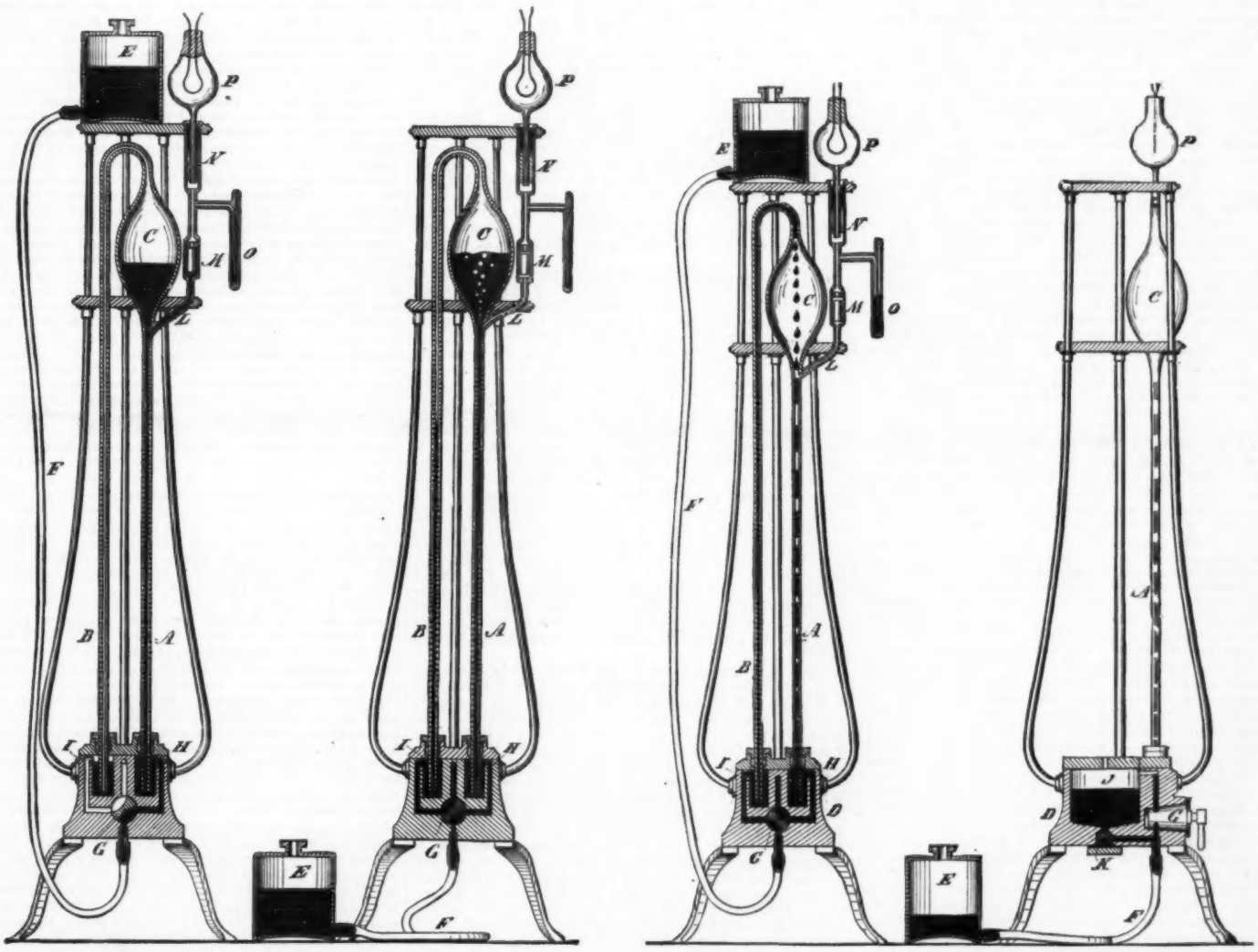


FIG. 1. FIG. 2. FIG. 3. FIG. 4.

NEVEUX'S RECENT IMPROVEMENTS IN VACUUM PUMPS.

A U-shaped pipe or tube, A, having two shanks, has a bulb, B, formed at the upper end of the shank A^2—that is, formed at that end of the shank at which the curve or bend is formed. The free ends of the shanks A′ and A^2 pass into pockets C′ and C^2 in a block, C, provided with a reservoir opening C^3. The upper ends of the pockets C′ and C^2 are connected by channels E′ E^2 with a valve-opening, F, containing a four-way-cock plug, G. From the said opening F a channel, F′, extends to the upper part of the reservoir-opening C^3, and from the said opening F a channel, H, extends down through a neck, J, to which a flexible tube or hose, K, is coupled, the other end of which flexible tube or hose K is coupled to the bottom of a mercury bottle, L. A channel, H′, extends from the bottom of the reservoir-opening C^3 to the channel H. By means of the four-way-cock plug G the channel E^2 can be brought in communication with the channel H, and the channel F′ can be brought in communication with the channel E′, as shown in Figs. 1 and 2; or by reversing the said cock-plug the channel E′ can be brought in communication with the channel H, and the channel E^2 can be brought in communication with the channel F′, as shown in Fig. 3. The cock-plug G is provided with a suitable handle, G′, for turning it. From the lower part of the bulb B a curved tube, M, projects upward, which is provided with an enlargement, M′, near the upper part of which a transverse apertured disk, N, is held, against the bottom of which a floating valve-plug, O, is adapted to be pressed by the mercury for the purpose of closing the aperture in the said disk N. Above the enlargement M′ a gauge, P, is secured to the tube M, and in the upper part of the tube M an enlargement, Q, is formed for receiving bulb or other vessel R, from which the air is to be exhausted. The tube A and reservoir block C are held in a suitable frame, on the top of which a table or platform, S, is formed, on which the mercury bottle L can be placed. If desired, the entire pump can be contained in a tank, T, which is filled with water or other refrigerating material to prevent the heat from evaporating the mercury, the valve-stem and the tube K being suitably packed in the walls of the said tank. A pipe, W, is provided, which extends upward and projects from the top of the table S, and is used to carry off the air that accumulates in the reservoir-aperture C^3. The bottom of the reservoir-opening C^3 is provided with an upwardly closing check valve, V, which closes the channel H′ and prevents the mercury from flowing into the said reservoir-opening C^3 from the bottom when the bottle L is raised.

The operation is as follows: The bulb or vessel R, from which the air is to be exhausted, is placed in the enlargement Q on the upper end of the tube M, and the four-way cock G is turned, as shown in Fig. 1, so as to connect the shank A^2, extending from the bottom of the bulb B, with the flexible tube or hose K. The bottle L is then placed on the table S, and the mercury flows from the bottle into the tube K, the channel H, the channel E^2, and into the pocket C^2, which is closed at its top and forms a mercury seal. The mercury then rises in the shank A^2 in the tube M, and presses the valve O against the bottom of the apertured disk N, thereby closing the aperture in the said disk. The mercury then rises in the bulb B until it flows out of the top of the same, and thus forces all the air out of the said bulb. When the mercury rises up to the lower end of the tube M—that is, to *b*—it automatically closes the lower end of the said tube M, and prevents the mercury from forcing the air in the bulb B up through the tube M, back into the vessel R. As soon as the mercury begins to flow through the bent tube at the upper end of the bulb B, the mercury bottle L is placed on the floor, as shown in Fig. 2. The mercury then flows down through the shank A^2 into the pocket C^2, the channel E^2, the channel H, the tube K, into the bottle L, whereby a vacuum will be formed in the bulb B, and the air will pass from the vessel R into the said vacuum, the same pressure being in the bulb B as in the vessel R. Then the mercury bottle L is placed on the table S again, thereby causing the mercury to rise and force the air out of the bulb B. The bottle is then lowered, and so on continually, whereby the air will be almost entirely exhausted from the vessel R. The gauge P shows the pressure in the vessel R. If more air is to be exhausted from the vessel R, the four-way-cock plug G is turned, as shown in Fig. 3, so that the shank A′ will be in communication with the channel E′, the channel H, and the tube K. The bottle L is then placed on the table S, and the mercury flows from the said bottle through the tube K, the channels H and E′, the pocket C′, and the shank A′, into the top of the bulb B, and then drops down through the same, and in dropping through the bulb the flow of mercury is so regulated by the cock G as to form a series of pistons, *a*, Fig. 3, between which pistons a small quantity of air is locked. The mercury-pistons descend and carry the air down into the pocket C^2, through the channel E^2, the channel F′, into the reservoir opening C^3, in which the mercury collects, the air escaping through the pipe W. Then the bottle is placed on the floor, and the mercury flows from the reservoir-opening C^3 through the tube K and back into the bottle. If all the air has not been exhausted from the vessel R, the bottle L is again placed on the table S, and the operation just described is repeated.

In the above-described pump the mercury never leaves the apparatus or pump, and there is no loss of mercury by handling the same. The pump is very compact, is simple in construction, and can be adjusted almost instantaneously to operate either as a Geissler pump or as a Sprengel pump, as circumstances may require. As a rule, a greater quantity of air is exhausted by using the pump as a Geissler pump, and when it is found that no more air can be exhausted by using the pump as a Geissler pump the cock is turned and the pump is operated as a Sprengel pump. The point *b* must always be a few inches above the barometer line from the level of the mercury in the reservoir.

[CONTINUED from SUPPLEMENT, No. 441, page 7034.]

THE GENERATION OF STEAM, AND THE THERMODYNAMIC PROBLEMS INVOLVED.*

By Mr. WILLIAM ANDERSON, M.I.C.E.

THE great enemy to attaining a high temperature in the furnace is the quantity of air required to insure perfect combustion. We have seen that 12·2 pounds of air are sufficient for the complete combustion of 1 pound of carbon, which will then develop sufficient energy to raise the temperature of the products of combustion to 5,150° absolute. In practice, however, a considerable excess of air has to be used, and the energy developed, which is not increased by the excess of air, is expended in heating a greater weight of gases, and consequently the temperature is lowered. Fig. 4 exhibits this effect by means of a curve which indicates the temperature of a furnace with from 12·2 pounds to 36·6 pounds of air per pound of carbon. Unfortunately no pyrometer exists by means of which the temperature of furnaces can be readily ascertained, but the melting points of steel have been determined with some accuracy. The late Sir William Siemens recently told me that cast steel with 1 per cent. of carbon melts at 3,192° absolute, while steel boiler plates melt between 3,462° absolute and 3,552° absolute, and that the latter is very nearly the melting point of platinum. On Fig. 4 I have drawn lines parallel to the base, indicating the extreme temperatures of melting steel, intersecting the curve of furnace temperature. You will observe that to melt boiler plates the quantity of air admitted should not exceed 1¼ times the theoretical quantity, and even for cast steel it must not exceed 1¾ times. Now, it is well known that crucible steel is melted in a common coke fire with a very moderate draught, and Mr. Webb tells me that in his locomotives the temperature of the furnace is sufficiently high to melt the cast steel fire doors should they accidentally drop in. It is probable, therefore, that the volume of air usually admitted is not more than 18 pounds per pound of fuel, and I have adopted that proportion in calculating the efficiency of the Cardiff boiler. Setting aside for the moment the effect of high temperatures on the materials of the boiler, it seems probable, as the late Professor Rankine has suggested, that by the use of forced blast and properly arranged furnaces, the amount of air necessary may be reduced to the theoretical quantity, and in confirmation of this view I may point to the rapidly extending use of under-grate blowers and of stoke-holes under pressure. In such cases the area of the firegrate is very much reduced, the energy of combustion heightened almost to its maximum point, and the efficiency of the boiler greatly increased, provided that the heating surface is sufficient to absorb the additional energy developed. Unfortunately, no accurate data relating to forced draught are available; I am obliged to be content with general statements, most of which tend in the directions I have indicated; indeed, until a trustworthy pyrometer is invented, the question must remain in an indefinite form.

The practical difficulty connected with raising the temperature of the furnace lies in the limited power of boiler plates to stand the high temperature, especially with hard water. With temperatures a little above that of melting steel, there does not appear to be any trouble when the water is soft, but at higher ranges boilers wear very fast, as, for example, when petroleum is used. This substance is composed of about 0·84 of carbon and 0·16 of hydrogen; 1 pound of the oil only requires 10·32 pounds of air for its combustion, and yields 22,136 units of heat. The temperature of the furnace, therefore, with only sufficient air to insure perfect combustion, is 8,216° absolute, and the curve on Fig. 4 shows that to bring the temperature down to that of an ordinary furnace would require the use of two and a half times the proper quantity of air. It is a well known fact that the furnaces of boilers burning petroleum suffer severely, and do not last nearly so long as the furnaces of coal-burning boilers. Where this defect has been got over it has probably been by lowering the temperature by the admission of an excess of air or steam. The temperature, t, of the products of combustion cannot be lowered below the temperature of the feed water. In condensing engines this is about 100°, but without enormously extending the heating surface this point cannot be attained, and the temperature of the chimney must be kept at least 100° higher, or at 200°. In the Cardiff engine the smoke temperature was only about 65° higher than that of the steam, and suppose that by means of feed heaters in the flue the temperature of the smoke could be reduced to 165°, then, with 18 pounds of air to the pound of coal, the fall of temperature from 389°—165° = 224°, would yield 19 pounds × 224° × 0·238 = 1,013 units, competent to raise 11·83 pounds of feed evaporated per pound of coal 85·6°, or to a temperature of 185·6°, which would still be 103° short of the temperature of the boiler; hence it follows that in a well proportioned boiler, carefully worked, the feed water cannot be raised in temperature more than 80° or 90° by means of heaters in the flues. It is sometimes said that a feed heater in the flue is no better than an extension of the heating surface of the boiler, but the above calculation will show that it is necessary to sever the heater from the boiler, and keep it at the lowest possible temperature, so as to take advantage of the low temperature of the smoke.

In practice the chimney temperature cannot be lowered to the point indicated, unless forced draught be employed; and I believe that, independently of the advantage gained by the improved duty due to the higher temperature of the furnace, there is a positive gain if moderate blast pressure be used. In the experiments made with H. M. S. Satellite and Conqueror, in 1883, it was found that ¼ inch air pressure in the stoke-hole produced the same result as the ordinary chimney draught, that ½ inch pressure corresponded to the steam blast in the chimney, and that 1 inch of pressure was sufficient to insure about 38 per cent. additional steam, but at a sacrifice of efficiency on account of the boilers being forced beyond their heat-absorbing power. Eighteen pounds of air at 60° measures 236 cubic feet, and if forced in under an inch of water pressure would absorb 1,224 foot pounds of work, or, assuming 50 per cent. duty, 2,447 indicated foot pounds per 1 pound of coal consumed. An engine burning 3 pounds of coal per I.H.P. per hour would absorb 91 units of heat in doing this work, but the heat abstracted from the smoke by lowering its temperature we have seen is 1,013 u., hence the power necessary to produce forced draught is only about ⅑ of that gained by cooling the smoke down to 165°. The necessity in any case of building chimneys to carry off the smoke has, no doubt, deterred nearly every one from trying forced draught, not as a means of temporarily increasing the boiler power, as is the case in torpedo boats and the larger war ships, but as the proper and rational way of exalting the duty obtained from fuel, namely, by raising the temperature of the furnace and lowering that of the smoke to the utmost extent possible in accordance with Carnot's theory. Unfortunately, the experiments which have been made by Messrs. Thornycroft, Messrs. Hawthorn & Co., and the Admiralty were not directed to the question of economy of fuel, but to the amount of steam that could, on an emergency and at any sacrifice, be got out of a boiler. Of course, the economic results were very bad, for although the temperature of the furnace was raised to a point which in the case of the Satellite and Conqueror made the tubes and seams leak, yet the chimney temperature was also raised even as high as 1,200°, a temperature considerably above red heat. Experiments are still wanting to show the result of exalting the heat of the furnace, while restricting the weight of fuel burned to such an extent that the heating surface of the boiler will take up all the heat developed, and part with the smoke at as little as possible above the temperature of the feed water.

* Lecture delivered at the Institution of Civil Engineers, session 1883-84.

We have seen that the duty of the Cardiff boiler was 0·892. How is the loss of 0·108, say 11 per cent., to be accounted for? In the first place, there is the obvious source of loss in radiation from the furnace to the ashpit and furnace door, and radiation and convection from the body of the boiler. The losses under these heads can be reduced to a small matter by properly arranged ashpits and doors, and by careful lagging. Next there is an indefinite loss arising from imperfect combustion. As already stated, Favre and Silbermann invariably found carbonic oxide in the products of combustion, and had to make corresponding corrections in order to obtain true results. The other source of loss lies in the transfer of heat from the heated fuel and gases, first to the boiler plates and then to the water. In the furnace the radiation from the incandescent fuel is very intense, and most of the heat is transferred to the boiler plates by this agency, because very few points of the fuel are in actual contact with the plates, and therefore are not in a condition to transmit by conduction. Iron and copper are probably only slightly diathermanous, that is to say, at the thicknesses which occur in practice, a very small proportion of radiant heat passes directly through the plates. Most of the information we possess respecting diathermancy is derived from Melloni's experiments, published in 1833; but, unfortunately, such ordinary substances as iron and copper do not enter into the long list of out of the way bodies he tested. All energy transferred by undulatory movement, whether heat, light, or sound, suffers absorption or reflection in passing from one medium to another; thus, in passing through the clearest glass, a ray of light emerges, shorn of some of its brilliancy, a part being reflected, and a part absorbed. The rays of heat, in like manner, are arrested to a varying extent, depending on the nature of the substance, in part reflected, in part absorbed; and Professor Tyndall's recent experiments on fog signals at the South Foreland show that sound is in like manner affected when passing through media of varying density.

The rate of transfer of heat through a plate varies directly as its thickness, directly as the difference of temperature on its two sides, and probably inversely as its absolute temperature; but, unfortunately, it is impossible to ascertain what the actual temperature of either side of a boiler plate is. It is quite certain that the side of the plate next the furnace is very greatly below the temperature of the fuel and flame, because, if it were not, copper furnaces and brass tubes, which melt below 2,000°, would very soon be fused; and, on the other hand, on the water side we have no means of telling how much hotter the plate is than the water. It is evident that the greater part of the radiation from the fuel must be reflected backward and forward, keeping up the temperature of the gases, which part with their heat energy by degrees as they pass along the flues. A certain amount of heat energy passing through a boiler plate is lost in keeping up the molecular motion of an imperfectly elastic material. It may be likened to the flow of water through a pipe inclined so as to be "in train," that is, till the rate of inclination exactly equals the retarding force of friction. The longer the pipe the greater amount of head will disappear in overcoming friction, and so the thicker the boiler plate the greater difference there will be in the temperature of its two sides, and the greater loss of heat in the passage of a given quantity.

Again, at the surface, where the heated gases touch the plates, and where the plates touch the water, there is a change of density and of material, and consequently a certain amount of loss arises. We do not know sufficient of the nature of heat-motion to say what takes place in its transfer by conduction from one body to another; but it is certain that wherever there is a joint, even in a bar of uniform material, there is a certain amount of resistance, and loss arises. To illustrate this I have arranged the following experiment: A round copper bar, ¾ inch diameter and 12 inches long, is placed over a Bunsen burner, so that the flame shall heat the center of the bar. One-half the bar is solid, the other is made up of four pieces screwed tightly together, so that there are three joints. At each end is a brass cup holding a measured quantity of water, and into each dips a thermometer. On heating the bar it will be found that the thermometer on the solid half rises more quickly than the one on the jointed portion. It is probable that even in the closest joints the contact is imperfect, and much of the heat has to pass through a thin layer of air. All who are familiar with forging are aware that defects in metal, invisible when it is cold, will show themselves when the metal is heated by the difference of luminosity, caused by imperfect conduction through the defective portion.

At first sight it would appear to be a matter of common sense that a boiler which contained its furnace within itself must be a better generator than a boiler with an external furnace formed of brickwork; but experience does not justify such a conclusion, and there are, in fact, good reasons why it should not. The brick-lining of a furnace is an extremely bad conductor of heat. In cupolas used for melting iron I have seen a lining worn down to between 1½ inches and 2 inches thick completely protect the sheet-iron casing, even in the hottest zone, so much so that the tar with which the iron had been coated was not sensibly affected by a temperature which must have been higher than 3,000°. Brick-lining is also a powerful absorber, and consequently radiator of heat, advantage of which property has been taken in ordinary reverberatory furnaces, in which the radiant heat emanating from the fuel is reflected down upon the hearth by a brick arch, and in many locomotive fireboxes, where brick arches are introduced in order to intercept and mitigate the destructive heat radiated from the fuel, and yield it again in a less intense form. The gases forming the products of combustion are very bad absorbers and very bad radiators of heat. Pure dry air and nitrogen are absolutely incapable of absorbing or radiating heat; they are not affected in the least by the passages through them of the most intense heat-rays. Carbonic acid is a somewhat better radiator, while the vapor of water is a good absorber and, therefore, a good radiator. Referring to Table II., it will be seen that the products of combustion of Llangenneck coal consist of:

	Cubic feet.	Per cent.
Carbonic acid	25·3	11·1
Vapor of water	7·6	3·4
Air and nitrogen	193·5	85·5
	226·4	100·0

85½ per cent. of air and nitrogen, mixed with only 14½ per cent. of carbonic acid and vapor; hence the gases, taken together, must be very bad radiators. This want of radiating power, however, can be overcome by letting them heat by contact some good, solid radiating substance, such as the particles of carbon forming smoke, or the soot-coated walls of brick or metal flues. It is for this reason that the perfect combustion of flaming fluel, in an ordinary boiler, is not necessarily, or even generally, attended with economical results. The smoky products of combustion, though at a lower temperature, are much more efficient radiators, and part more readily with what heat they have, than the transparent and hotter products of perfect combustion. I have arranged an experiment to illustrate this, Fig. 5.

Here is a common Bunsen burner, from which the air is shut off, and which has been burning with this luminous and comparatively cold flame since the commencement of the lecture. The radiant heat has been concentrated by means of a concave silvered mirror and polished cone on to the blackened bulb of a large air thermometer. The liquid has attained its maximum height, and has been steady there for some time. I now admit air, and produce the intensely hot but transparent Bunsen flame. You will see little or no difference in the temperature indicated by the thermometer; the colder flame is luminous because it is full of white-hot particles of carbon, which are good radiators; while the hot flame consists of air, nitrogen, carbonic acid, and vapor, which, taken together, are bad radiators. But if I hang a spiral of iron wire in the Bunsen flame, it begins to glow, and the thermometer, by its rapid rise, declares that the heat of the flame is now being powerfully radiated from it. Now, it is a notorious fact that hardly any economy results from so arranging a boiler that it shall produce no smoke, the reason being that the products, deprived of particles of carbon, become deficient in radiation, and carry the unused heat away to the chimney. If any decided advantage were obtainable by the suppression of smoke, acts of Parliament would not have been necessary to enforce it. The truth is that a different class of boiler is required for hydrocarbon fuel, such as flaming coal and petroleum, as distinguished from carbon fuel, such as the anthracites and coke. In the first class wide flues are desirable, because combustion continues far along the flues and the radiant powers of the smoke are high; in the latter case the products must be subdivided as much as practicable by means of small tubes, so as to bring the gases as intimately as possible into contact with the heating surfaces. But here a caution must be given as to the use of small tubes, for unless the chemical changes have taken place completely before the gases reach the tubes, there is danger that the cooling down which follows the subdivision of the gases will arrest the process of combination—put the fire out, in fact—and allow unconsumed gases either to escape altogether, or to ignite after they leave the tubes, doing no useful work. I have arranged an experiment which shows this process very fully. An ordinary Bunsen burner is made to burn with a small luminous flame. Pieces of ½ inch gas-tube, of lengths varying from 1 inch to 6 inches, are placed over it in succession. The shortest tube allows the flame to pass through; the longer ones extinguish it, but the partially consumed gases can be lighted again at the upper ends of the tubes. The action is the same as in the miner's safety-lamp; the gases are cooled below the temperature at which chemical reaction can take place. A tube which in its cold state extinguishes the flame, if heated will permit it to burn.

I found, by means of experiments made with boiler-tubes, placed over a jet of crude gas from a Siemens producer, that 6 feet was the maximum length which a boiler tube of 3 inches diameter should have, if combustion were intended to go on within it. It is a matter of common observation that in marine boilers, especially those in which there is very little space between the fire-grate and the tubes, the gases are extinguished and relight at the up-take end, making the chimney red-hot; the glare of the flame, and even the flame itself, being often seen at night, or even against a dark cloud in the day time. It is manifest that any arrangement by which the gases could be stirred about in the flues would assist in depriving them of their burden of heat; this can be accomplished, to some extent, by bafflers in the flues causing eddies, or, as has been recently proposed, by giving the smoke a spiral motion as it passes up the chimney, the said motion being propagated backward through the flues. Owing to water being an extremely bad conductor, and almost completely adiathermanous, it is commonly held that the lower halves of tubes and internal flues are inactive in transmitting heat to the water, and no doubt this is the case, but they act powerfully in an indirect manner. The soot lodging in them absorbs, and therefore radiates, heat powerfully; the gases in contact with the soot heat it, and this heat is, by radiation, transferred to the upper halves of the tubes and flues, and so made available. In the same way, in sectional boilers set in ovens, the gases are greatly subdivided and tormented; they beat up the sooty brickwork setting and partitions, and these transfer the heat by radiation to the boiler surfaces, suffering little to escape by conduction and radiation into outer space.

The general conclusions to be drawn from the above considerations are, that the most efficient boiler will be found to be one in which a moderate forced draught is used, the chimney being merely lofty enough to carry the smoke to a sufficient height to avoid creating a nuisance. A feed-water heater should be fitted in the flue, beyond the boiler. If the water be soft, an external furnace is admissible; but if hard, a flue furnace acts best, with a flue of large diameter. In both arrangements the boiler plates immediately over the grate should, probably, be protected by fire-brick linings. The space between the grate and the tubes, if any are employed, should be sufficiently voluminous to admit of complete combustion, and the tubes should be used only to absorb the energy from the heated gases. In such an arrangement the conditions laid down by Carnot can be satisfied, and the highest duty obtained from the fuel. In the indicator diagram, Fig. 3, I have assumed that the rate of transmission of heat from the gases to the water is in direct proportion to the difference of temperature, but this is probably not strictly correct, because the conductivity of substances varies inversely as the temperature, probably as the absolute temperature; hence the rate of transfer of heat at the furnace end will be slower in proportion than at the chimney end, but to what extent it is impossible to say, be-

cause the mean temperature of the boiler plates is unknown. It is certain, however, that it is below even the melting point of lead, or 630°, because lead safety-plugs are frequently used, even in locomotives, and they do not melt out unless there be a want of water. If we assume the mean temperature of the plates at the furnace end to be 500°, and that of the chimney end 350°, then the rate of transmission at the cooler end will be about 18 per cent. greater than at the hotter. Were it not for the imperfect absorption of radiant heat and reduced conductivity, caused by high temperature, ebullition over and about the furnace would be so violent that uncontrollable priming would surely take place. The rate of transmission of heat by the heating surface of a boiler can now be approximately calculated. We have seen, in the case of the Cardiff boiler, that the combustion of 41 lb. of coal per hour is capable of yielding 525,572 units of heat. The mean temperature of the gases was estimated at 2,313° absolute; that of the water in the boiler, 784°; hence the mean difference of temperature was 1,529°. The heating surface being 220 square feet, U, the number of units of heat absorbed per square foot per difference of 1° per hour would be:

$$U = \frac{525{,}572 \text{ units}}{1{,}529^\circ \times 220 \text{ sq. ft.}} = 1{\cdot}56 \text{ units.}$$

In this case, glowing fuel and heated gases impart, chiefly by radiation and convection, their energy to water at a lower temperature. The action is the inverse of that which takes place where hot water or steam is used for heating buildings; we might expect, therefore, according to the doctrine of exchanges, that the work done per unit of surface and difference of temperature would be approximately the same. In the 48th volume of the *Proceedings* will be found a curve from which the units of heat given out by a 2 inch wrought iron hot water pipe may be ascertained. For a difference of 190° between the temperature of the water and the air being heated, 590 units per square foot per hour were given out; this is equal to 3·1 units per square foot per difference of 1° per hour, or about double the amount realized at the Cardiff trials. This is accounted for partly by the fact that the plates and tubes of the boiler of the portable engine were, on the whole, thicker than the metal of the heating pipes; partly by the conducting power of the surfaces having been reduced in consequence of their high temperature, but chiefly by the circumstance to which I have already alluded, namely, that the temperature of the furnace plate, for a considerable portion of the smoke run, is very much less than that of the glowing fuel and gases, hence the mean temperature of the plates would be considerably lower than that of the products of combustion. Until a trustworthy pyrometer is invented, it will be impossible to determine more accurately the rate of transmission, but it may be stated that in practice 12 square feet of flue heating surface, measuring only the half over the gases, or 10 square feet of small tube surface, measured in the same way, will transmit the heat necessary to evaporate 1 cubic foot of water per hour from and at 212°. The French allow 1 square meter, or 10·76 square feet, per horse power, but I am not aware that the value of a French boiler horse power has been accurately defined.

The next point to claim our attention is the velocity of the gases through the flues and tubes of boilers. The weight of air ordinarily necessary for the combustion of 1 lb. of coal is 18 lb., producing at 32° Fahrenheit, or 492° absolute, 226 cubic feet of gases. This volume when heated up to the temperature of the furnace, will become—

$$\frac{226 \text{ cubic feet} \times 3{,}777^\circ}{492^\circ} = 1{,}735 \text{ cubic feet; and assuming that}$$

the gases cool uniformly along the heating surface, then, in the case of the Cardiff boiler, where the ratio of the tube surface to the total surface was as 194·6 square feet to 220 square feet, when the gases reached the tubes in the firebox they would have had an absolute temperature

$$= (3{,}777^\circ - 849) \times \frac{194{\cdot}6}{220} + 849 = 3{,}439^\circ,$$

and the volume $= \frac{226 \text{ cubic feet} \times 3{,}439^\circ}{3{,}777^\circ} = 1{,}579$ cubic feet.

By means of a similar calculation, the volume at the smoke box end of the tubes, where the temperature was 849°, is found to be 390 cubic feet. The boiler at the trials consumed 41 lb. of coal per hour, and the area through the tubes was 1·22 square feet; hence the velocity per second at the fire box end was $= \frac{41 \text{ lb.} \times 1{,}579}{60' \times 60' \times 1{\cdot}22 \text{ sq. ft.}} = 14{\cdot}74$ feet per second,

and at the smoke box end 3·64 feet per second, the mean being a little more than nine feet per second. The boiler was, however, worked to only about one-third of its power. From a number of boilers in actual work, with chimneys of moderate height, I have deduced that for a temperature of 400°, a velocity of 10·8 feet per second is admissible; this corresponds to 10 square inches of flue section per boiler horse power (which I define to be one cubic foot of water, evaporated from and at 212°) and for a consumption of 1 lb. of coal to 10 lb. of water converted into steam. There is one source of loss in connection with the combustion of fuel which must be touched upon, and that is the heat absorbed in the work of displacing the atmosphere. The gases evolved from the fuel at the furnace end have their temperature lowered by an amount corresponding to the work performed in displacing the air, and this work is very considerable; but as the gases part with heat in passing through the boiler, they contract, and the atmosphere, in falling, restores the energy absorbed in lifting it. At the chimney end, however, if the gases leave at 400°, 396 cubic feet of smoke per lb. of coal are being forced into the atmosphere, and work corresponding to 447 units per lb. of coal consumed is lost, the amount forming about 3½ per cent. of the available heat of combustion. With regard to chimneys I will only remark that, except where it is necessary to carry smoke clear of buildings, there is nothing gained by making them more than from 50 to 80 feet high. Unless the sectional area be sufficient, at least ten square inches per boiler horse power, the chimney is very likely to become "in train," that is to say, the motive force gained by lengthening the hot column of gases is counterbalanced by the friction which the sides of the chimney oppose to the passage of the smoke. I have met with two or three instances of this kind; indeed, in tall chimneys, with a good deal of internal taper, considerable benefit has often been derived by reducing the height. The effective area of a chimney should be measured at its smallest part.

The last consideration which will occupy our attention is the conditions of the water and steam in the boiler. First as to the water. Water is not only almost adiathermanous, or opaque to radial heat, but it is also a very bad conductor; the consequence is that neither by radiation nor by conduction can any considerable depth of liquid be heated. Advantage is taken, though I believe unconsciously, of this adiathermancy in the globes of water, used by diamond cutters to concentrate light on to their work; glass lenses cannot be used, because the spot of light in the focus of the lens would also be a spot of considerable heat, but the water lenses allow the light to pass, while they completely arrest the rays of heat. In the palace of the Grand Duke Constantine, at St. Petersburg, I have seen a very efficient fire screen formed by a sheet of water falling from a pipe, placed in front of and above the fire place, into a trough concealed by the fender. The mobility of water, however, neutralizes the want of conductivity and diathermancy, and heat is distributed by convection. The molecular motion of the heated boiler plates is communicated to the films of water in contact with them; the consequent expansion which ensues causes a diminution of specific gravity and the films rise, making room for fresh layers which get heated in their turn. When the water has risen to a temperature corresponding to that of steam at the particular pressure, the convective action is augmented in consequence of the molecular motion transcending the limits of aqueous cohesion, causing the water to become impregnated with steam bubbles, and its density thereby still further reduced. The body of water, however, lying below any upward heating surface, such as the upper half of flues and tubes, is not so favorably placed; the heated layers remain in contact with the plates, they cannot rise vertically, and the viscosity of water prevents any rapid sliding along inclined or curved surfaces. The heat has to be carried downward, partly by induced currents caused by the convection currents of the water, above the heating surfaces, gradually drawing up the water below them, and partly by heat conducted downward by the boiler plates from the upper heated portion of the shell of the boiler. This action, which is necessarily very slow, is especially noticeable in boilers which have no external flues, such as those of the marine type, and in these steam must be got up very gradually, so as to allow the water in the bottoms to get heated by the slow process I have described, otherwise the difference of temperature, between the top and bottom of the boilers, produces strains which are apt to end in troublesome leaks. It is very advisible, therefore, if on the score of durability alone, to set boilers in external flues, whenever possible.

Steam in contact with water, when the action is sufficiently energetic, is always more or less impregnated with particles which are an assemblage of molecules, which have not succeeded in emancipating themselves from the bands of cohesion, but which have been carried up by the energy of those molecules which have. The molecular theory of evaporation is that the molecules of a fluid, to which the energy of heat has been imparted, perform excursions of varying extent and velocity, their motion being incessantly modified by the collisions which the molecules receive from each other. It is only to the average motion that a definite value can be ascribed; and although the average motion in fluids is much less than in gases, yet the motion of some molecules of a heated fluid may be as great and even greater than the average velocity of the molecules of a gas. Hence, if molecules near the surface of a liquid happen to have this extreme velocity, and if the movement happens to be outward, from the mass, then those molecules will escape from the fluid, and form part of the substance of the gas. Conversely, the molecules of the gas, which in their excursions strike the water, have their momentum reduced to such an extent, by communicating their motions to other molecules, that they are unable again to free themselves, and they once more become parts of the liquid—they are condensed, in fact. When evaporation has ceased from the surface of a liquid, it does not mean that the action above described has ceased, but merely that a balance has been arrived at between the molecules ejected and the molecules falling back and retained in the liquid. So soon as, by the application of heat to the liquid, or cold to the gas, the balance is destroyed, evaporation sets in with greater or less rapidity, according as the disturbance of equilibrium is more or less considerable. When particles of water are carried up into the steam space, their return to the water is interfered with by the viscosity of the atmosphere of steam in which they find themselves. Many solid substances, and all liquid and gaseous ones, are more or less viscous. The researches of Sir W. Thomson, of Poiseuille, Graham, O. E. Meyer, Helmholtz, Stokes, and Clerk Maxwell, have determined the laws which govern this property of matter. The rate at which a particle will fall through a viscous substance is directly as the difference of density between the particle and the substance, directly as the square of its diameter, inversely as the absolute temperature, and independent of pressure; hence it is obvious that the decrease in the diameter of a particle will cause a very rapid decrease in its rate of falling. It is easy to satisfy one's self of this truth, by mixing up a little ordinary mud with water. It will then be seen that the coarser particles soon fall to the bottom, the smaller ones follow gradually in the order of their linear dimensions, but there will remain a residuum of very fine particles, which take days and even weeks to settle down completely. Some waters, notably those of the Nile, are impregnated with particles so minute that they cannot be separated by filtration through sand or filter paper, nor will they subside in any definite time.

In the atmosphere, again, particles of moisture, smoke, or dust subside in the same manner at varying rates. Professor Tyndall found, in his beautiful experiments instituted to overthrow the doctrine of spontaneous generation, that it required three days for all the dust to settle down in a box 14 inches long by 14 inches high, and 8½ inches deep, so as to become what he called "optically empty," that is to say, that a vivid ray of light should pass through without revealing its track. When the impurities are so thick that they sensibly alter the specific gravity of the gas, then the whole mass moves together; this phenomenon may be seen in fogs and thick, cold smoke, which will lie in hollows and pour down valleys like water, and present a level upper surface. All substances, even gases, vary much in viscosity. The coefficients of hydrogen and carbonic acid are smaller than the coefficients of air, while that of oxygen is greater. It has been calculated that a drop of water 0·001 part of an inch in diameter will fall 0·8 of an inch, or 0·067 foot, per second in the region of the clouds, and if the diameter of the drop be 0·0001 of an inch, the rate will be 0·01 of the above, or about ⅛ inch per minute. As far as I know, the coefficient for steam has not been determined.

It is evident that if an upward current exists in the medium through which the foreign particles are sinking, they will move with a velocity which will be the difference between the velocity of the current and of their own downward tendency; if the upward current is more rapid than the rate of falling the particles must be carried upward, and will be so carried as long as the velocity of current is maintained. Now, in steam boilers the proportion which the free water surface bears to the power of the boiler varies very greatly, and the velocity with which the steam rises from the surface is not only inversely as the area of the free surface, but also inversely as the pressure, while the viscosity is unaffected by the pressure. In Table III. I have collected ten varieties of boilers, and have given the heating surface, water surface, rate of evaporation, steam pressure, and velocity per second with which the steam rises from the water. I have arranged them in the order of this velocity, and, bearing in mind that a drop 0·001 inch diameter falls at the rate of 0·067 per second, it will be noticed that in the plain Cornish and the two-flue Cornish multitubular boilers, the upward velocity is less than this, while in the others it is greater. The three-flue marine boiler, in which an enormous heating surface is packed under a very small water surface, the velocity is 0·127 foot, and the tendency to carry up water, or to "prime," is very strong, while the stationary locomotive, with a velocity of 0·169, could with difficulty be worked at the rate of evaporation given. The Roots boiler is an exceptional case, because there the steam is superheated, the evaporation, in fact, completed in the steam space.

TABLE III.—PRIMING OF BOILERS.

Class of Boiler.	Velocity of Smoke in Tubes 600°, 10 lb Water, 1 lb. Coal.	Heating Surface.	Water Surface.	Water Evaporated per Hour.	Steam Pressure.	Steam Generated per Second.	Velocity of Steam rising from Water Surface.
	Feet per sec.	Sq. Ft. —	Sq. Feet.	Cub. Feet.	Lb.	Cubic Feet.	Feet per sec.
1. Plain 2-flue Cornish, set in brick flues.....	—	439	139·3	36·0	50·0	4·07	0·029
2. 2-flue Cornish multitubular, set in brick flues.	10·76	512	127·8	48·15	45·0	5·43	0·043
3. Single-flue marine.....	9·58	296	53·13	40·0	60·0	3·90	0·074
4. 8 h.-p. Cardiff portable engine, as tried.....	4·36	123	20·51	7·794	80·0	0·615	0·030
5. 8 h.-p. Cardiff portable engine worked full power.....	13·08	123	20 51	23·38	80·0	1·845	0·090
6. 3-flue marine.....	10·54	852	104·8	152·0	70·0	13·34	0·127
7. Compound locomotive, L.N.W. railway.....	39·82	595	50·3	179·7	150·0	8·49	0·169
8. Locomotive used as stationary, over worked. ...	35·15	664	58·54	150·0	100·0	9·92	0·169
9. Roots sectional	—	460	9·72	28·7	70·0	2·52	0·259
10. Vacuum pan 8 feet diameter.....	—	386	50·6	198·6	-13·5	1,026·0	2·66

The vacuum pan, Fig. 6, is one of the most instructive cases. The velocity is very high, on account of the immense specific volume of the steam at 13 lb. vacuum; the boiling is consequently very violent, and the priming is so great that "savealls," or collectors, are a necessary equipment of a pan. Pans are always provided with peepholes, or lunettes, by means of which it is possible to observe what is going on. Over the wild commotion of the water surface rests an atmosphere of steam as transparent as the air; no water particle is large enough to break up or intercept the passage of the light, and yet large quantities of sugar and water accumulate in the savealls, raised by the high velocity of the steam, which is 2·66 feet per second. The particles must therefore be extremely small and numerous. The existence of solid matter in water, and in the steam derived from it, is often revealed by the accumulation of sediment in the steam chests and other steam spaces of engines. Boilers working on the Nile, for example, show no indication of priming till the floods come down, but then the extremely fine particles of mud are carried up by the molecules of steam into the steam space, and not being able to sink faster than the steam rises, are carried over into the engines. It follows from the thermo-dynamic theory of evaporation and viscosity which I have just laid before you, that steam-domes and strainers cannot be of any use to check ordinary priming. The area of a steam-dome, or of a strainer, is necessarily many times smaller than the area of the free water surface; hence the velocity of the steam passing through them must be very much greater than that of the steam rising from the water, and if, in the latter situation, it is competent to carry up particles, it is plain that they cannot be precipitated in the steam dome or the strainer, where the velocity is higher. This fact has been found out by experience, for steam domes are very seldom applied nowadays to any kind of boiler, though in the case of marine boilers both steam domes and strainers may be found useful to obviate the coarser kind of priming due to the violent motion of the vessel. The most successful way of separating water carried along by steam is to cause the latter to impinge against a plate interposed at right angles to its course, to cause it to turn down and pass under the edge of the plate, and continue its course on the other side. (Fig. 7.) The particles of water dashed against the plate adhere to it, and, trickling down, drop off at the lower edge, but in particles too coarse to be again carried up by the steam. The water so collected is returned to the water space of the boiler. It is evident that it is impossible to assign any numerical value to the amount of priming to be expected, since it depends, not only on the form of the boiler and the steam pressure, but also on the quality and condition of the water, the latter, if impure, varying from day to day. The slowness with which smoke falls to the ground, after escaping from a chimney, proves, first, that the particles of soot are very minute, and, secondly, that there are not a sufficient number of them sensibly to affect the specific gravity of the gases in which they are suspended. The inference is that the waste of fuel in the form of smoke is really not very serious, and not sufficient to counterbalance the loss I have already alluded to, of radiant power in the

products of combustion, caused by perfect chemical combination.

The practical deduction to be made from the statements which I have had the honor of laying before you is that no very marked improvement is to be expected in boilers. All sorts and shapes have been tried, and the best of them do not surpass the duty obtained at Cardiff, where extreme skill in management was combined with a comparatively light demand on the powers of the boiler. When inventors come to you and propose to effect the usual saving of 50 per cent. in your fuel consumption, you will be able to fix them to something more definite, and then, if they understand the subject at all, you will find that their pretensions will be materially modified. You will also have noticed the important part that absolute temperature plays in all thermo-dynamic problems. I trust that the day is not far distant when all thermometers will be graduated from absolute zero. It will be but realizing Fahrenheit's idea, only with better information, and although it will at first sound strange to hear people talk, for example, of a very cold night with the thermometer at 460°, meaning the zero of Fahrenheit, still we shall soon get accustomed to that, and will have the advantage of abolishing negative readings and mistakes in calculations arising out of them. I have now completed the task assigned to me by the Council, and have shown how the potential energy of fuel is converted into the potential energy of steam at high pressure and temperature. It will be the duty of my successor at this table, Mr. E. A. Cowper, on the 17th of January next, to show by what mechanical contrivances the potential energy of steam is converted into the energy of motion, suited to the wants of man. My subject is by no means exhausted, but time will not permit me to touch on the important points relating to incrustation, corrosion, and some other matters of interest.

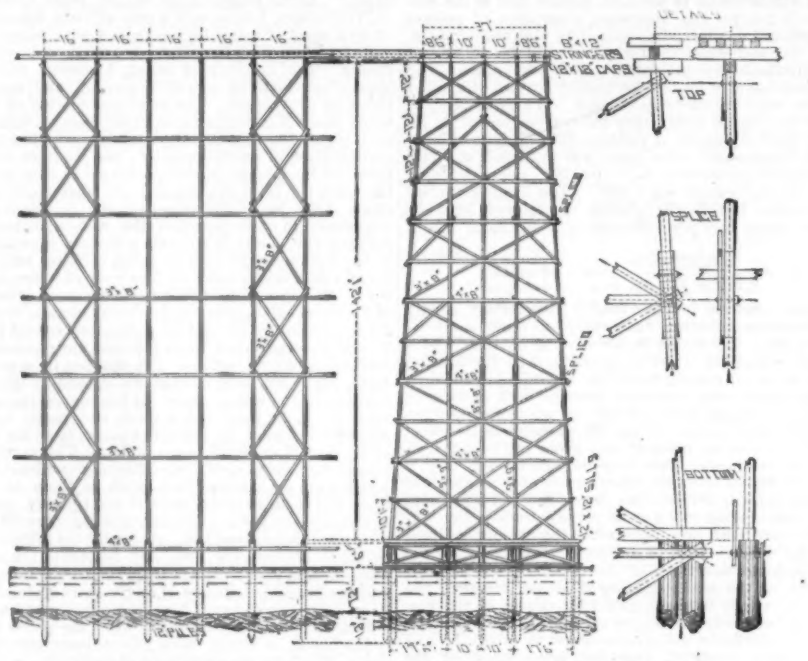
To the late Professor Rankine, I believe, is due the honor of having first pointed out the true principles on which the duty of a boiler should be estimated, namely, by comparing the work actually done with the potential energy of the fuel used, and I cannot conclude this lecture without paying a tribute of admiration to one who was a brilliant ornament to our profession, who combined in his own person the qualities of a profound mathematician, of an acute physicist, and of an excellent practical mechanic, and whose early death has deprived the profession of a member who has done so much for its advancement, and the science of thermo-dynamics of one of its most devoted and successful votaries. The very day on which I handed the MS. of this lecture to Mr. Forrest, one of the brightest stars in our firmament was hastening to his setting. I had intended sending a proof to Sir William Siemens, in the certain expectation that, with the kindliness and consideration which have marked every action of his life, he would have looked through my work, and given me, and this institution, the benefit of advice founded on his extensive and accurate knowledge. You must have noticed how often I have quoted his name, and the regrets I have expressed in the want of a high temperature pyrometer. In writing to me in October last about the melting point of steel, Sir William Siemens concludes by saying: "I am now following up a plan of getting reliable indications of temperature exceeding the limits of melting steel." In addition, therefore, to the already too numerous causes of regret we must add this, that the production of a trustworthy high-temperature pyrometer has been indefinitely postponed; for I know of no man living so competent to accomplish a task which will severely tax the most cultivated intellect, and require the command of exceptional facilities for experiment. I spoke of Sir William Siemens as a star which had set for ever; his influence, however, will not so soon fade away. Just as this generation is profiting by the solar radiation which fell on the earth countless ages ago, so will the labors of our late colleague form a store of knowledge, potential with respect to this and succeeding generations, destined to confer advantages, greater than we can now estimate, to the ever-advancing cause of science.

THE RONDOUT BRIDGE.

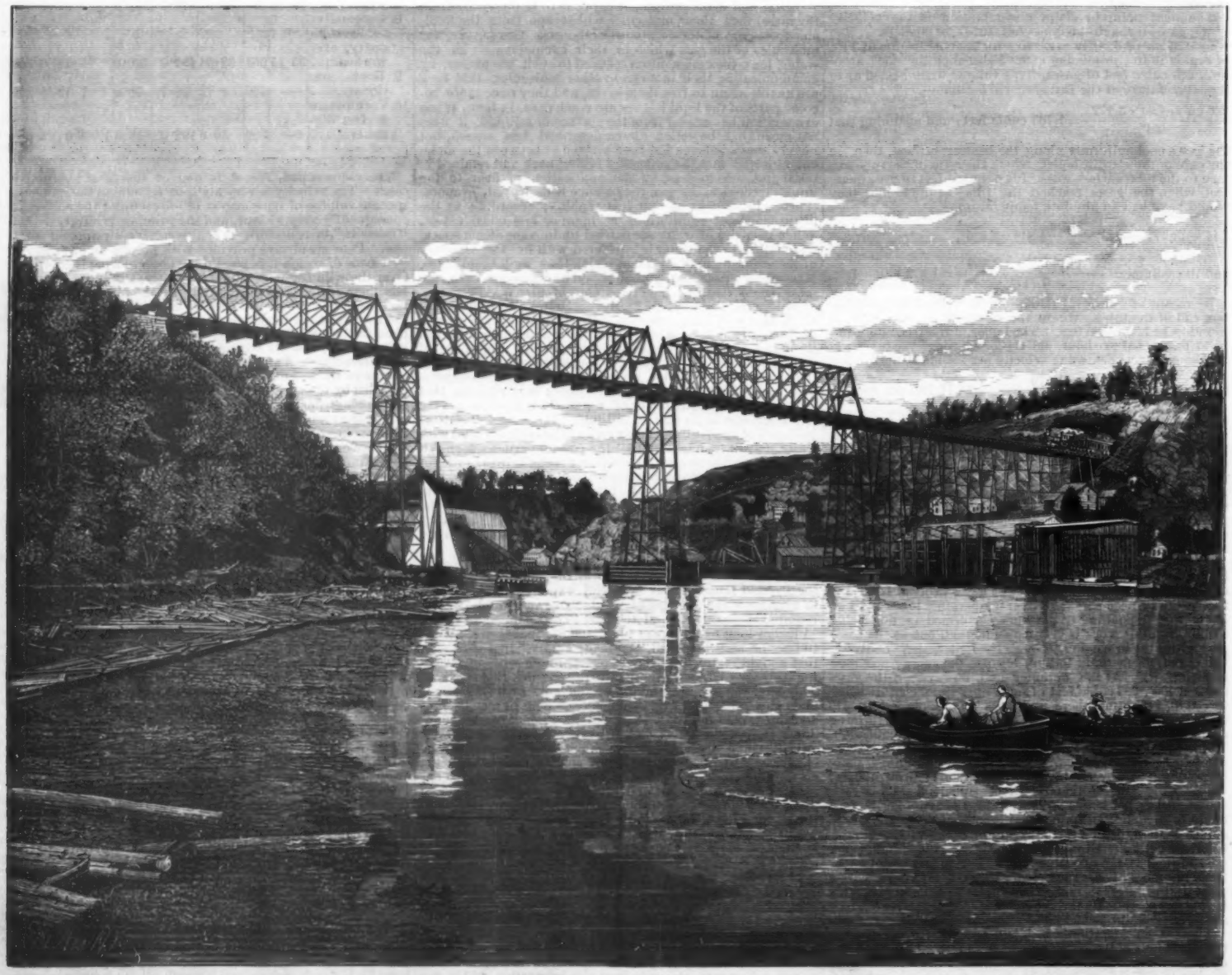
THE New York, West Shore, and Buffalo Railway crosses Rondout Creek at an elevation of 150 feet above water, in order to permit the passage of large schooners and barges. There is a large amount of coal, cement, and flag stone that annually passes this point, and a drawbridge, which the height of the present structure makes unnecessary, would have seriously interfered with the operation of the road.

The line of the road leaves the top of a hill of the same elevation as the bridge, crosses the three spans, then a long viaduct, and thence through a tunnel in the opposite hill. The spans are of the following lengths, beginning at the south (left of the engraving):

One of 163 feet, one of 24 feet, and one of 264 feet. They rest upon three iron piers of 15 by 30 feet section. The via-



FRAMEWORK FOR ERECTING THE SPANS.



RONDOUT BRIDGE, NEW YORK, WEST SHORE, AND BUFFALO RAILROAD.

duct is 531 feet long, supported on piers—thus making a total length of 1,244 feet. The weight of the iron entering into the construction is 2,000 tons. The work of erection was begun November 8,1882, and the first train crossed May 8, 1883. The total cost of the bridge was about $350,000.

The iron work was designed and constructed by Clarke, Reeves & Company, of Phœnixville, Pa., in accordance with specifications and detailed directions of Col. Walter Katte, chief engineer of the North River Construction Company, and E. L. Corthell, chief engineer, and A. Lucius, engineer in charge of bridges, of the New York, West Shore, and Buffalo Railway.

The bridge is 29 feet wide from center to center of trusses, the viaduct being the same from center to center of column caps. The first span has a height of 32 feet, and the other two a height of 45 feet. It is a pin connected, wrought iron bridge, the iron having a minimum ultimate tensile strength of 50,000 pounds per square inch of original sectional area before fracture. The end and intermediate posts and top chords, as well as the columns in the piers, are of the pattern known as Phœnix columns. The wooden floor consists of transverse floor timbers, extending the full width of the bridge, supporting rails and guard beams. According to the specifications for bridges of this size, they must carry the dead load consisting of the iron in the structure and a floor weighing 400 pounds per lineal foot of track consisting of rails, ties, and guard timbers only, and a moving load for each track—supposed to be moving in either direction—consisting of two consolidation engines, coupled, followed by a train weighing 2,240 pounds per running foot. In order to provide for vibrations and wind pressure, the bottom lateral bracing in through bridges is proportioned to resist a lateral strain of 450 pounds for each foot of span.

The viaduct is composed of lattice girders supported upon six iron piers, the distance between facing columns of the piers being 50 feet in all except that next the bridge, which is 60 feet. Much trouble was experienced in obtaining a suitable material upon which to build the piers, and in some instances excavations to the depth of 60 and 80 feet had to be made before finding a good foundation. The bridge piers rest on masonry, built on piles driven to refusal.

The placing in position of a structure of this magnitude at so great a height involves great care and much labor, and its rapid and successful completion makes it a subject well worth studying. No false work was used in erecting the viaduct. The piers consist, practically, of four iron columns resting on beds of masonry, and firmly held in position by struts and ties. After the foundations had been completed the columns were raised in place, when a gin pole (a wooden mast having a pulley at its upper end, through which a hoisting rope passes) is fastened to them by iron bands. A rope passes from a hoisting engine through a block at the base, thence through the pulley in the gin pole. By this means the several parts were raised into position and secured. The work was completed, section by section, to the full height, and the track laid. As soon as the first section had been finished a traveler, operating on top, assisted in the work of raising the balance.

Very different and much more difficult was the task of erecting the spans. In this case it was necessary, in order to support the great weight of iron, to build a framework of heavy timber of strength sufficient to bear the load and resist the wind which sometimes sweeps through the gorge with great violence. Our drawings show a side and transverse elevation, with details of the top, bottom, and splice. All bolts were three-quarter inch, all diagonal transverse braces were 3 inches by 8 inches, all horizontal transverse braces were 4 by 8 inches, all longitudinal braces 3 by 8 inches, with X bracing between outside and center legs. This framework was supported on piles; the distance from the top of the piles to the caps was 142 feet. Three hundred thousand feet of timber were used and 416 piles. Putting the span together after this had been finished was comparatively easy. About two-thirds of the total cost of erection was for the false work, engines, blocks, tackle, and other appliances. The total cost of erection was about 1¼ cents per pound. The cost was from one-third to one-half a cent per pound greater than it would have been in summer, owing to last winter being an unusually inclement one. Much of the time the ropes, stagings, etc., were covered with ice.

THE FRENCH IRON CLADS L'INDOMPTABLE AND LE MARCEAU.

EVER since the appearance of La Gloire—the first iron-clad built by Mr. Dupuy de Lome—France and England have been striving to rival one another in the creation of more and more formidable types. The fact must be recognized that these two countries have, in a manner, proceeded side by side, although the ideas of engineers as to the role of the apparatus with which iron-clads are armed and the general aspect of their vessels are quite different.

On the present occasion we shall describe to our readers two of the most recent iron-clads that have been added to our navy—L'Indomptable and Le Marceau. Owing to the distribution of her artillery, which sweeps the entire horizon, and to the possibility of the large turret guns being able to cross their fire, the Indomptable possesses undoubted merits. Every ship that makes an attack upon her will have to expose herself to the fire of at least one of the turret guns.

The Indomptable, which was launched at Lorient, September 19, 1883, was built after plans made by Mr. Sabattier, Director of Naval Constructions. She is 278 feet in length, 59 feet in breadth, and 24·75 feet in depth. Her draught is 23 feet forward, and 24·5 feet aft. Her displacement, when completely equipped, will be more than 7,000 tons. Her estimated speed is 14 knots.

The entire hull, including the frame, is of steel. Her hold is constructed after the cellular system, and is divided into a large number of water-tight compartments by 9 transverse bulkheads that rise to the iron-clad deck and are intersected by partial longitudinal ones.

The armor, which extends from stem to stern, is 11·8 inches thick fore and aft and 19·7 inches amidship. It is of compound metal, that is, iron faced with steel. The turrets are armored with this same metal 16·7 inches in thickness. The breech of the turret guns is further protected by a small steel cupola. The total weight of the armor, including that of the turrets, is 1,744 tons. The deck itself is armored with steel plates 3¼ inches thick. The engines are expected to yield a power of 6,000 horses, with 85 revolutions for an ordinary run, and 90 for the greatest speed. They are of the vertical three-cylinder type, and actuate two screws that have a pitch of 18·7 feet. Steam will be furnished them by 12 cylindrical two-furnace boilers placed in two water-tight compartments. The coal bunkers form at the two sides 4 compartments that protect the engines and boilers.

The cabins, which are upon the armored deck, are protected by a second deck of steel, and above this there is a spardeck.

The armament of the Indomptable will consist of 2 sixteen and one-half inch guns, weighing 77 tons, throwing 1,540 lb. projectile, and placed in the *barbette* turrets; 4 four-inch guns placed upon the upper deck; and Hotchkiss guns placed both upon deck and in the tops. The large guns are to be maneuvered by hydraulic apparatus. Their field range is 135° on each side, starting from the axis of the vessel. The vessel will be provided with two tripod masts for signals, with tops armed with Hotchkiss guns. This ship will probably not be finished until the end of 1885, when her construction will have lasted nearly eight years. Her total cost will be $2.068,000, say $1,397,000 for the hull and accessories, $105,600 for her armament, $213,200 for the engines, and $304,000 for the artillery equipment.

Figs. 1, 2, and 3 show the principal arrangements of the vessel.

The second vessel, Le Marceau, is a squadron iron-clad that was launched at La Seyne on the 16th of January, 1884, and built by the Societé des Forges at Chantiers de la Mediterranee after plans by Mr Huin, an engineer of the navy. This vessel is 330 feet in length, 65 feet in width, and

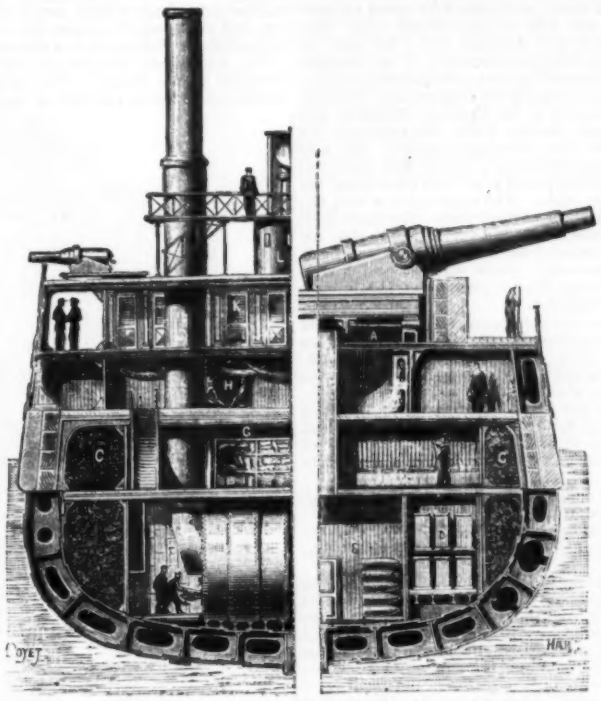


FIG. 1.—THE FRENCH IRONCLAD L'INDOMPTABLE. (Transverse Sections.)

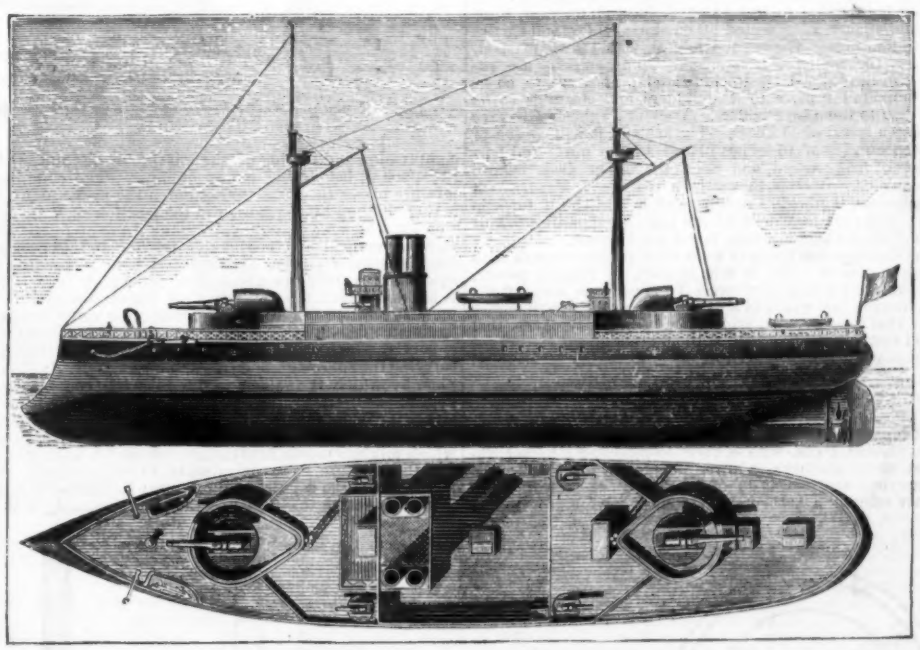


FIG. 2.—GENERAL VIEW OF L'INDOMPTABLE.

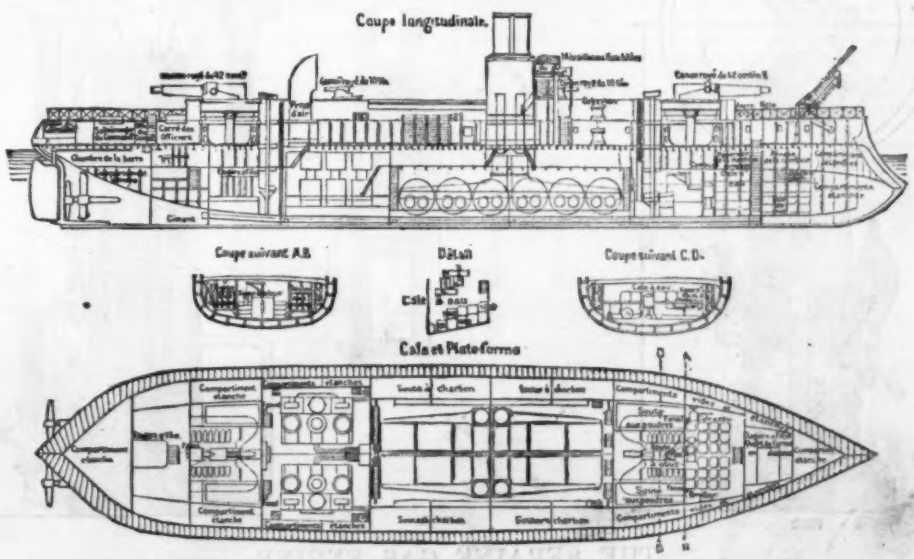


FIG. 3.—THE IRONCLAD L'INDOMPTABLE. (Longitudinal Section and Plan.)

25 feet in depth. Her upperworks will be protected by 16·73 inch armor-plate, her lower by 13·75 inch plate, and her deck by 3 inch plate. The fore and aft turrets will be armed with two 13·5-inch guns, while two other turrets placed amidships will carry guns of 10 inch caliber. In addition, there will be two 5·5 inch guns fore and aft, eighteen others of the same caliber in the battery, and twenty Hotchkiss guns to complete the armament. The turrets are to be armored with 15·75 inch plate, and be further protected by a steel shell about eight inches in thickness. The vessel will be provided with four apparatus for launching torpedoes, two amidships, and two at the stern. Two laterally placed engines will give her a speed of 16 knots. A supply of 600 tons of coal (that may be increased to 800) will permit her to run 1,500 miles at full speed, and 3,500 with speed reduced to 11 knots. Finally, she will displace 10,581 tons. Her hull, properly so called, will displace but 3,740 tons, or about 35 per cent. of the total displacement. If we compare this result with good types of English construction, we shall find that the Devastation, alone, gives a proportion of 36 per cent. Other iron-clads, such as the Hercules, Monarch, and Dreadnought have much heavier hulls, that represent not less than 43 per cent. of their total displacement. The hull is constructed according to the cellular system, and comprises a double shell. The external shell is of iron plate from the garboards to the armor plate. The upper part, which extends to the iron-clad deck, is of steel plate. The inner shell is of steel plate. Iron was selected in preference to steel for the submerged parts because of the destructive action of salt water upon the latter material. Steel was selected for all other parts, on the contrary, for the purpose of obtaining a great reduction in the weight.

The motive apparatus that the Marceau is to be provided with will comprise two independent and like vertical engines of the compound type, each of which will actuate a screw. The great power of each engine has rendered it necessary to have recourse to the use of three juxtaposed cylinders.

The normal power of this vessel's engines, with a natural draught, will be that of 5,548 horses, but, with a forced draught, will rise to that of 12,000 horses. The number of revolutions will be 72 per minute in the first case and 90 in the second.

The French fleet will comprise three other analogous iron-clads—Le Hoche, Neptune, and Le Magenta.

In conclusion, we shall say a few words about two of the most recent iron-clads built by the English—the Conqueror and the Colossus.

The Conqueror is 288 feet in length, 58 feet in width, and 21 feet in depth. Her draught is 22 feet forward and 24 feet aft. Her armor extends from the stem to a certain distance from the stern, and amidships there is an armor-plated redoubt for the protection of the commander, the apparatus for maneuvering the artillery, and the smoke-stacks. The armor-plate is from 9 to 10 inches thick at the load-water line, and only 7 inches thick below that point. It is bolted to a framework of teak. The armor of the transverse partitions is one inch thick, while that of the deck is about one-quarter inch. The turret, which is located forward, is 21 feet in diameter, is protected by one-inch armor, and carries two 43-ton guns. The superstructure, which is all of steel, contains the cabins of the officers. The engines are expected to show 4,500 H. P., indicated. They are to be of the compound type, with 3 cylinders, and steam is to be furnished to them by 8 boilers. They are expected to give the ship a speed of 15 knots. The armament will consist of 2 43-ton guns, 2 of 16 inches placed in the ports and permitting of firing astern, and 2 on the upper deck behind steel shields. Besides these, there will be 7 Nordenfeldt mitrailleuses, 2 guns in the tops, and 6 Whitehead torpedo guns. The only mast will be the one for signaling. This vessel, like the Indomptable, is not yet finished.

The Colossus has recently been tried at Portsmouth with complete success. She is comparable, as regards power, with the ships described above. To give some idea of the complication that exists in a modern iron-clad, it will suffice to say that the Colossus, aside from the two engines that propel her, is to be provided with 36 other steam motors for different purposes.—*La Nature.*

IMPROVED GAS ENGINE.

THE gas engine illustrated below has been designed by M. J. Seraine, Paris, with a view to obtaining a higher efficiency by exhausting at a lower pressure, or in other words, by carrying the expansion of the heated gases through a greater range. The theoretical efficiency of a gas engine, such as the Otto, cannot under present designs be more than 0·33, and M. Seraine attributes much of this to the high pressure at which exhaust takes place. He says, for instance, that if the exhaust pressure could be by expansion reduced to one atmosphere, the theoretical efficiency would be increased to 0·63, and that taking the actual duty of an Otto gas engine as 0·106, the efficiency is but 0·321 of the theoretically possible efficiency.

To improve things, M. Seriane points out that increases of stroke and range of expansion will not secure the result, because the greater stroke will be accompanied by a greater quantity of gases, and wasted heat in a high temperature exhaust will remain the same. He has, therefore, designed an engine in which the compression of the charge is rendered independent of the volume swept through by the motor piston, and yet to use this piston for compression, so as not to complicate the engine with a special compressing cylinder.

Fig. 1 illustrates the principle on which is based the construction of the engine. The part, A, of the cylinder, of which the section is reduced by the piston-rod, serves for the compression and forcing of the mixture of gas and air into the space, J, below the motor cylinder. The compressed mixture passes thence to the bottom of the piston at A^1, and is there ignited by the burner in the position shown. Figs. 1 and 2, which we reproduce from the *Annales Industrielles*, show a vertical gas engine in elevation and section, of 6 kilogrammeters power, or 4,329 foot-pounds per minute, equivalent to 0·131, or a little over one-eighth horse-power. A is the cylinder, the upper part of which is used for compressing; B, the piston; C, the distributing valve for the inflammable mixture through the port, a; b, the igniting port; c, port by which the burnt gases escape; D is a slide face, carrying the admission port, a^1, and escape port, c^1; E is the plate by which the valve and the slide face casting, D, are kept in position; F, inlet cock; G, suction valve admitting air for the compression, admitting the air by the central part and the gas by a series of holes, g g; H is the valve through which mixture passes into the compressor; I, pipe conducting the mixture from the valve, H, to the reservoir, J; R, reservoir for the compressed mixture; K, clarinette receiving the gas from the meter by the pipe, f, passing it to the burner by the pipe, i, and to the suction valve by the pipe, j, and the India-rubber bag, k; O, cam commanding the distributing valve. The consumption of the gas is given by our authority as 600 liters of gas per horse-power per hour, or 21·2 cubic feet. Whether this is indicated horse-power or actual is not stated, but it is very low—*The Engineer.*

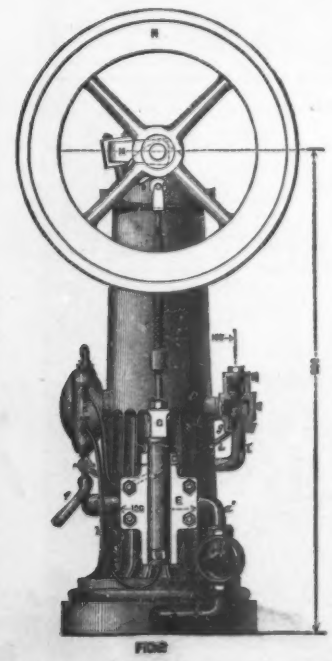


FIG. 2

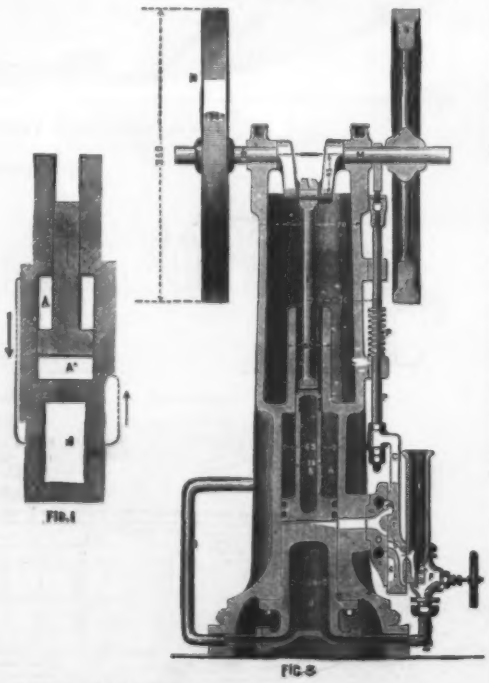
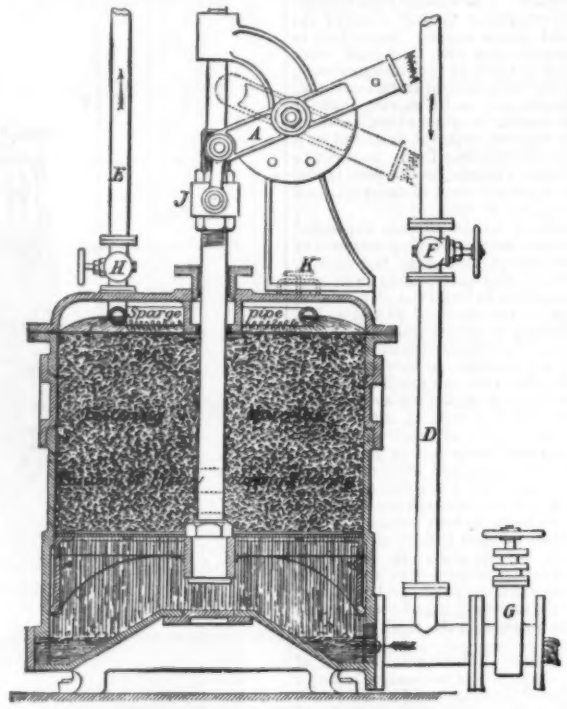


FIG. 3

THE SERAINE GAS ENGINE

IMPROVED SPONGE FILTERS.

THE problem of constructing a filter for steam users and manufacturers that should be able to deal with large quantities of muddy river and canal water, and should at the same time be capable of being easily and efficiently cleaned, has been solved, says *Engineering*, by the Pulsometer Engineering Company, of the Nine Elms Iron Works, by the adoption of an elastic filtering material, which when compressed forms a compact bed through which the water percolates, but when released immediately expands, freeing itself from the accumulated dirt, and offering little resistance to the flushing current that is then sent through it in the opposite direction. The material employed is sponge contained in a cylinder, and normally compressed between the cylinder end and a piston. While the cleansing operation is being conducted, the piston is alternately raised and lowered, the action on the filtering medium being similar to that ordinarily adopted in washing a soapy sponge; it is first allowed to absorb water until the pores are filled, and then the water is squeezed out, carrying a part of the mud with it, the process being continued until the effluent water is clear.

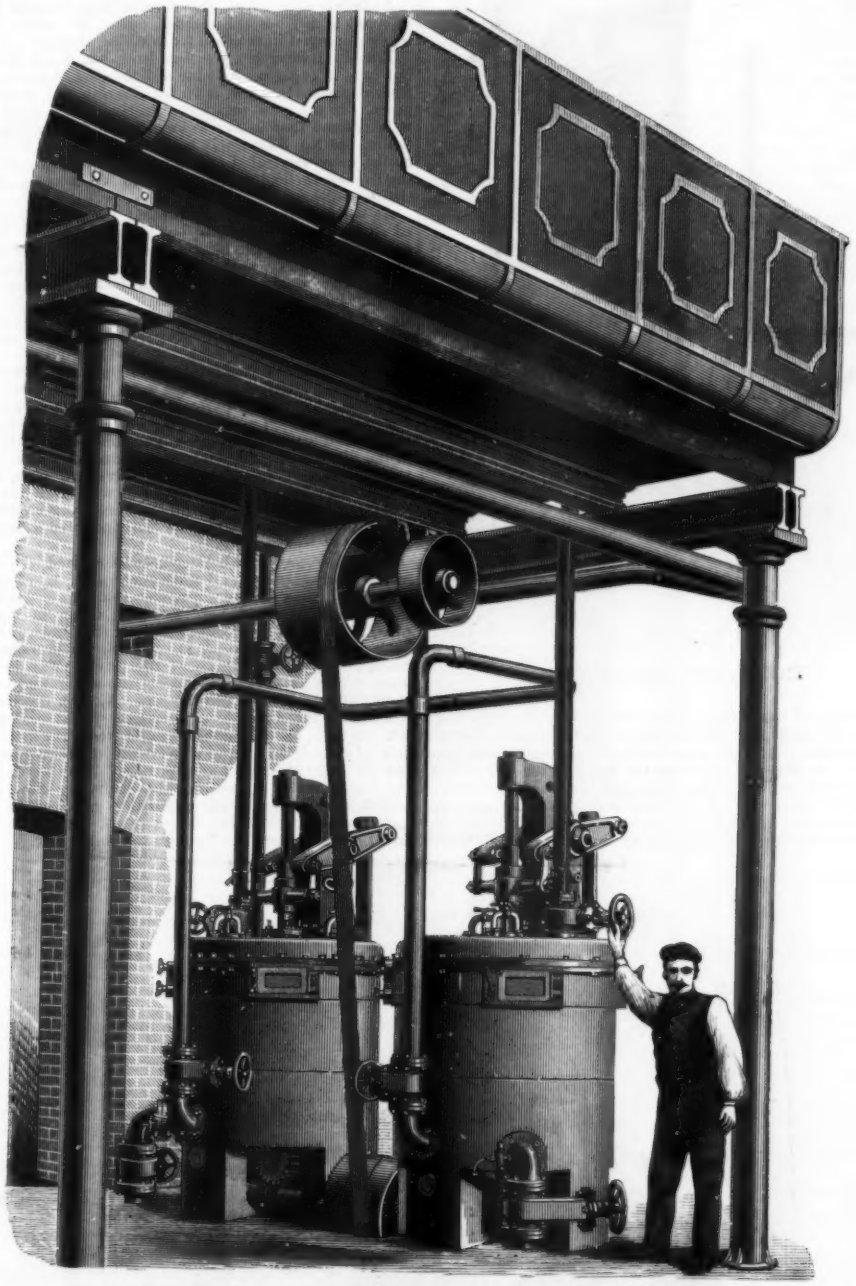


IMPROVED SPONGE FILTERS

A very successful installation of these filters is now in operation at the works of Messrs. Garton, Hill & Company, saccharum manufacturers, Battersea, London, where it is supplying feed water for eight boilers, each 30 feet by 7 feet. Two filters of the largest size are employed, and when the five remaining boilers that will be required when the works are complete have been put down, will run night and day. At the present time, when the river is particularly muddy, the effluent water from the filter is bright and clear, and as far as appearance goes is similar to the company's water, which is also drawn from the Thames, though of course at a higher part of the river, and has been submitted to an elaborate process of settling, and filtration by sand beds. The immense quantity of mud eliminated by the filter is made manifest as soon as the cleaning process is commenced, when it pours out in a thick stream, gradually becoming clearer and clearer until the turbidity ceases. It is not contended that sponge has any power to extract the soluble impurities contained in water, or to counteract the ill effects of contamination by sewage. All that is claimed for the filter is that it will rapidly cleanse large quantities of muddy water sufficiently for every manufacturing purpose, and for feeding boilers both on shore and in river boats, and that with a very small amount of care it will remain in good working order for years. Large numbers of these filters have been delivered both at home and abroad, one firm having already ordered nine for use on river steamers in Demerara. These filters are made in five sizes, the smallest of which will pass from 100 to 150 gallons per hour, and the largest 2,000 to 3,800 gallons.

The construction of the filter is clearly shown by the illustrations, one being a vertical central section, showing the parts as they appear while the filter is being cleaned, and the other a perspective view of the double installation of the saccharum works. The apparatus consists of a cast iron copper lined cylinder fitted with a piston, formed of a circular grating covered with wire gauze. The filtering medium is contained between this piston and a perforated plate, I, which forms the face of a collecting chamber constructed in the cylinder cover. The piston rod is coated with gun metal, and passes through a stuffing box to a guide fixed on the cover. Between the gland and the guide it is provided with a crosshead, J, whose position can be adjusted by means of a screw thread on the rod. This crosshead is connected by two links to a double lever, A, by which the piston can be raised and lowered in cleansing the sponge. The agency for operating the lever varies according to circumstances and the size of the filter. In the annexed section a hand lever is shown, while in the installation at Messrs. Garton, Hill & Company's works a connecting rod couples the lever to a crank disk driven by a worm and worm wheel and fast and loose pulleys. In some cases it is more convenient to dispense with the lever and to employ a steam cylinder mounted upon the guide bracket after the manner of a steam hammer cylinder. In order that there may be no

liability of the apparatus to set fast, even if it be neglected, the metallic contact between the piston and the cylinder is made as narrow as possible, and wooden guiding strips are fitted to the outer ends of the strengthening ribs. The water to be cleansed enters at the lower part of the filter at D, and rising through the piston and the compressed layer of sponge, escapes by a pipe, E, from the chamber formed in the cover, to the tank where it is to be stored, the propelling force being preferably the action of gravity. When the filter is to be cleaned, the supply of dirty water is cut off by closing the valve, F; the mud cock, G, and air inlet, K, are opened, and a portion of the filtered water allowed to flow back to waste, while at the same time the piston is slowly raised and lowered.



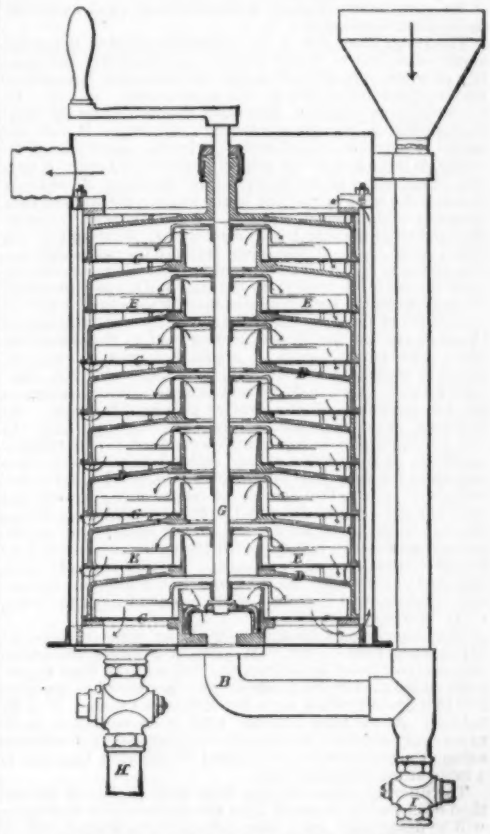
IMPROVED SPONGE FILTERS FOR BOILERS.

PIEFKE'S FILTER.

THE filtering of water is, from both a sanitary and manufacturing point of view, one of daily increasing importance; our rivers are becoming more and more polluted, and the value of space is increasing too rapidly to admit of large sand filtering beds and settling tanks being adopted for the purification of water for domestic and manufacturing purposes. The filter which we illustrate from *Engineering* is designed to combine in the smallest possible space the largest and most effective filtering surface, and differs not only in construction but also in the material used from any previously employed. It is the invention of Mr. Carl Piefke, chief engineer of the Berlin Water Works, and is manufactured by Messrs. G. Arnold & Schirmer, engineers in Berlin; it has been adopted in several large industrial establishments on the Continent on an extensive scale.

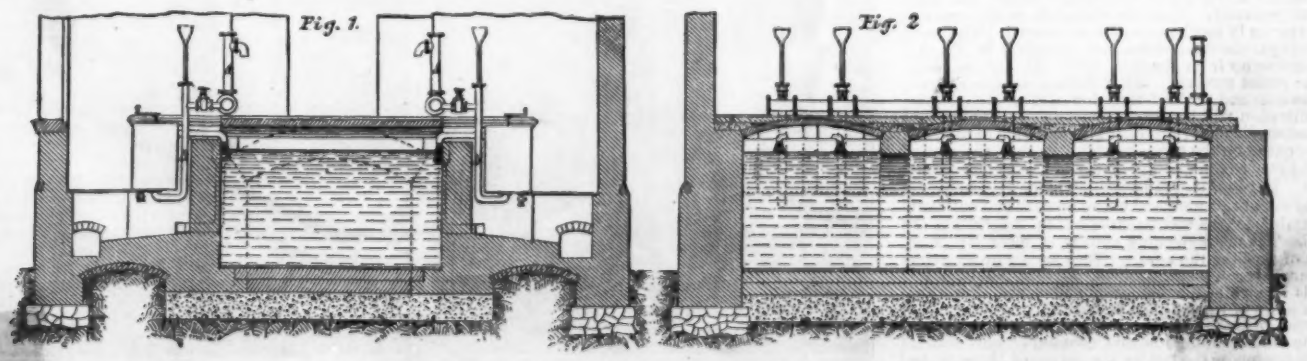
Our illustrations, Figs. 1 and 2, show a general arrangement of a filtering plant, consisting of twelve of these filters, each capable of purifying 1,100 gallons per hour. A large reservoir in the center of the building collects the clean water; the filters are grouped two and two, in two rows of six each side, and are supplied with water through the mains, A, A, while the funnels serve to charge the filters with the filtering material. Three tanks, together with thirty-six filters, have been recently fitted up by Messrs. Arnold & Schirmer at a large bleaching establishment near Warsaw, where about 800,000 gallons of filtered water are used daily.

The filter itself, shown in section in Fig. 3, consists of a wrought iron casing containing a number, here twelve, of perforated brags, C, which form the bottom of flat, bell shaped cast iron vessels, D, the whole grouped one above the other inside the casing. The water to be filtered enters by the funnel, A, and through pipe, B, runs into the vessel, overflowing in the direction of the arrows, and after passing through the filtering material spread upon the perforated brags, C, rises till it overflows at the outlet. The filtering medium is chemically prepared cellulose or vegetable fiber, and is variously treated according to the purpose for which the filtered water is to be used, or, in other words, according to the degree of purity required in the filtered water. Its price varies accordingly; the best quality is charged at 75s. per cwt., and a filter capable of purifying 1,000 gallons of water per hour requires, for its first charge, about 3 lb. of filtering material. To charge the apparatus, the fiber is mixed with water to a thin paste and admitted through the funnel, when it deposits in an even layer over the perforated surfaces, C, and the filter is then quite ready for action. After about 1,200 gallons of water have been purified per square foot of filtering area, the latter requires cleaning or washing out; this is performed in a very simple manner by charging the filter with water in the usual manner, and at the same time slowly rotating the vertical spindle, A, which carries the scrapers, E, and by means of which the filtering material is suspended in the water, the latter washing out the impurities. As soon as the water runs clear again the rotary action is stopped, and the tap, H, on the bottom of the casing opened to allow the water to run off, and the filtering material to settle, when the filter is again ready for use. The quantity of water which may be filtered before it



PIEFKE'S IMPROVED RAPID FILTER.

becomes necessary to clean the fiber depends, of course, largely on its state of impurity, and it is advisable to use as a guide the pressure required to force the water through the filter. This should not exceed from 3 ft. to 4 ft. of water pressure, and it is therefore best to place the funnel about that height above the overflow. At each cleaning a small quantity of filtering material is naturally washed away with the impurities; this amounts to about ten per cent., which quantity should be replaced by admitting it with the water. For the purpose of washing out the filter it is not necessary to use filtered water, nor is water of any particular pressure required; it may be simply charged through the delivery pipe. If at any time it becomes desirable to entirely empty the filter of the filtering material, water is charged through the delivery pipe or into the open vessel, and the tap, I, at the bottom of the supply pipe, A, is opened, when the fiber will run out with the water. The apparatus can be recharged as described above, and for the complete operation of cleaning one filter, one man only is required for about ten minutes. This filter is recommended by the manufacturers for purifying water for all purposes, a small size measuring only 9 in. in diameter and 15 in. high inside, and carrying only about 1 oz. of filtering material, is especially manufactured as a portable filter for military purposes, capable of filtering over 80 gallons of water per hour; this is apparently a very handy form, and certainly a very valuable addition to the field equipment of an army. We understand that Messrs. Arnold & Schirmer are about to make arrangements for the manufacture of these filters in this country.



PIEFKE'S IMPROVED RAPID FILTER.

THE HYATT FILTERS.

THESE improvements are manufactured by the Newark, N. J., Filtering Company.

Their design is due to the inventive activity of Mr. J. W. Hyatt, the president of the company.

In these machines the movement of the water through the filter and the means of removing the impurities arrested by the filtering medium are striking and novel.

While these filters are adapted to the use of animal charcoal, wood charcoal, and various other filtering materials, there are very few cases where anything like the quantity and quality of water can be filtered by these substances so efficiently and economically as by the use of suitable sand. Where sand can always be kept clean and without waste, as can be done in the Hyatt filters, it is the most effective and at the same time least expensive of all filtering substances for purifying large quantities of water.

The economy of sand for filtering is shown, for instance, by the fact that the sand in a filter containing 50 bushels costs but a mere trifle, while 50 bushels of animal charcoal would cost about $150. The sand will last for many years without deterioration, while the charcoal, which while fresh is excellent for decolorizing water, will become unfit for use in two or three months.

We shall therefore speak in this article of sand as the filtering agent employed.

The Hyatt filter No. 1 is especially adapted to houses, small steam boilers, laundries, etc., and wherever the quantity of water to be filtered is supplied through a ⅝ inch pipe under a pressure of five or six atmospheres, or less. Its operation is as follows: The water is admitted by the compound cock, A, and passes through the valve, B, into the sand. The course of the water, during the operation of filtering, is indicated by the arrows shown in the cut. A portion of the water passes upward from the valve, B, entirely through the sand by the side of the filter to the top, and then descends to the discharge pipes. Other portions traverse the sand from the side at various heights, between the top and bottom, and all escaping through the perforated discharge tubes, C, D. The upward current of water entering from the valve, B, loosens up the sand and keeps it in a state of mild ebullition for a distance laterally something less than one-fourth of the diameter of the filter. The sand is loosened the most and has the greatest motion next to the side of the filter, while further away it gradually moves slower, and becomes closer as the distance increases from the side, until motion ceases, and the sand compacts more and more by the pressure of the water passing through. By this plan, in the first part of the filtering operation, the coarsest impurities in the water are retained in a distributed condition by the portion of sand which is in a loosely moving state; the next finer impurities are arrested a little further away, where, the current of water being slower, the sand is not so much disturbed; finer particles again are stopped further away by the still denser sand; and so the process goes on by gradations, till the water comes into sand which is motionless and compact. In this compact sand, adjacent to the outlet, the fine and last remaining impurities are obstructed, and pure water passes through the tubes, C, D, into the outlet pipe, E.

This description applies to each of the three varieties of Hyatt filters here shown. It permits a larger amount of water to be filtered by a given quantity of sand than is possible where the silt and impurities are permitted to accumulate in a dense stratum upon the motionless surface of a filter bed. At the same time the sand is in condition to be more easily cleansed, the impurities being loosely distributed among the particles of sand instead of adhering together in a more or less tenacious mass.

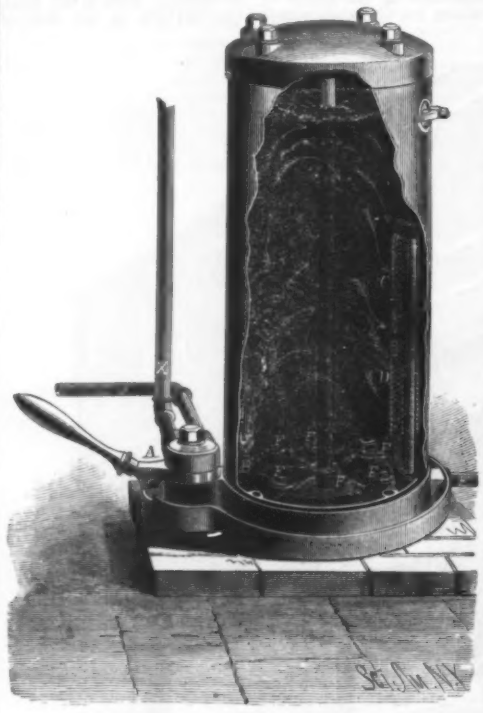
The filtering process having thus been explained, the method of cleansing the sand from the accumulated impurities will be described. As a rule, the sand in a filter should be thoroughly washed at least once a day, although this depends upon the character and amount of impurities which the water contains. In warm weather, especially, cleansing should be done frequently to prevent decomposition of the organic matter remaining in the sand, which makes filters which are only cleansed at long intervals fountains of filth instead of purity.

In washing Hyatt filter No. 1, the handle of the compound cock, A, is turned to the left as far as it will go. This shuts off the water from the valve, B, and permits it to enter through the small valves, F, which are distributed at regular intervals in the bottom of the filter bed. From these valves the water rushes upward through the sand, loosening and carrying with it all of the silt and impurities that have been retained in the sand while filtering, and discharging them through the central pipe, G, from which it issues by one of the openings in the compound cock, A, into the waste pipe, V. Five or ten minutes for washing is usually quite sufficient; and if this be done regularly each day, the filter will be kept in the most perfect order and will do its work for a practically indefinite period, as there is no waste of sand, and the filter is constructed of bituminized iron and has no working parts liable to get out of order. After washing, the handle is turned to the right until it stops, and filtering is at once resumed.

Some of these filters are arranged for the introduction of the unfiltered water over the sand instead of at the bottom. Is is then filtered downward and discharged through perforated metal below. In a filter of the form and capacity of house filter No. 1, this arrangement will give finer filtration but a less quantity of water. The plan of washing the sand is, however, as above described.

Hyatt filter No. 2 is made in diameters of 40, 50, 96, and 120 inches respectively. They are worked in gangs or series of from two to ten in number, as may be desired. The method of filtering is the same as has been described in No. 1, the water passing up from the inlet valve, B, and passing across to the outlet screens. By reference to the arrows shown in the cuts and to the description of filter No. 1, this method of filtration will be clearly understood. In filters of 40 and 50 inches diameter, the inlet is at one side of the bottom and the outlet on the opposite side, so that the water must be subjected to the filtering action of a sufficient quantity of sand. But in filters of larger diameter the water is admitted through the center, and passes upward and outward to the circumference, as will be explained in description of filter No. 3. The distinguishing feature of filter No. 2 is the process of washing the sand. They are set up in series of two or more, because one of them, in turn, contains no sand, but is idle while the others are filtering. For example, in a series of three filters, as shown in the cut, two of them are filled with sand and are used simultaneously while filtering, the third standing idle and containing only water.

In washing, suppose the last in the series of three to be the idle one. The outlet valve, D, in the first filter, is closed; the waste valve, I, and the valve at the top of the pipe, E, are opened. The water coming in through the valve, B, can then only escape through the pipe, E. This pipe in large filters is made tapering and terminating very near the bottom of the filter. Through this pipe the water rushes up into and through the horizontal pipe, H, and discharges into the top of the third filter. In doing so the water carries with it the sand from the first filter, conveying it all into the third filter in about ten minutes. This carrying process is facilitated



THE HYATT FILTER NO. 1.

by a current of water forced from the upper part of the filter through the small pipe, C, loosening up and helping to separate the impurities from the sand during its passage through the pipe, H. As the sand falls into the water in the third filter, the separated impurities flow out with the excess of water through the open valve, I, into the waste pipe; the sand, being thoroughly washed, settles, and remains in the filter. Now, this washing of the sand from the first filter into the third being accomplished, the valves, C and E, in the first filter, and waste valve, I, in the third, are closed; the inlet valve, A, in the third filter and its outlet valve on the opposite side are opened, and filtration is immediately commenced. Next the middle filter, or number two, may be washed, its contents being washed into the first filter precisely as had been done in the preceding case. Following in order, at the proper time, the sand in number three is discharged and washed into number two. And so, in regular order of succession, the filters are cleansed. About twenty minutes or half an hour each day is all the time required to keep a series of three in perfect order.

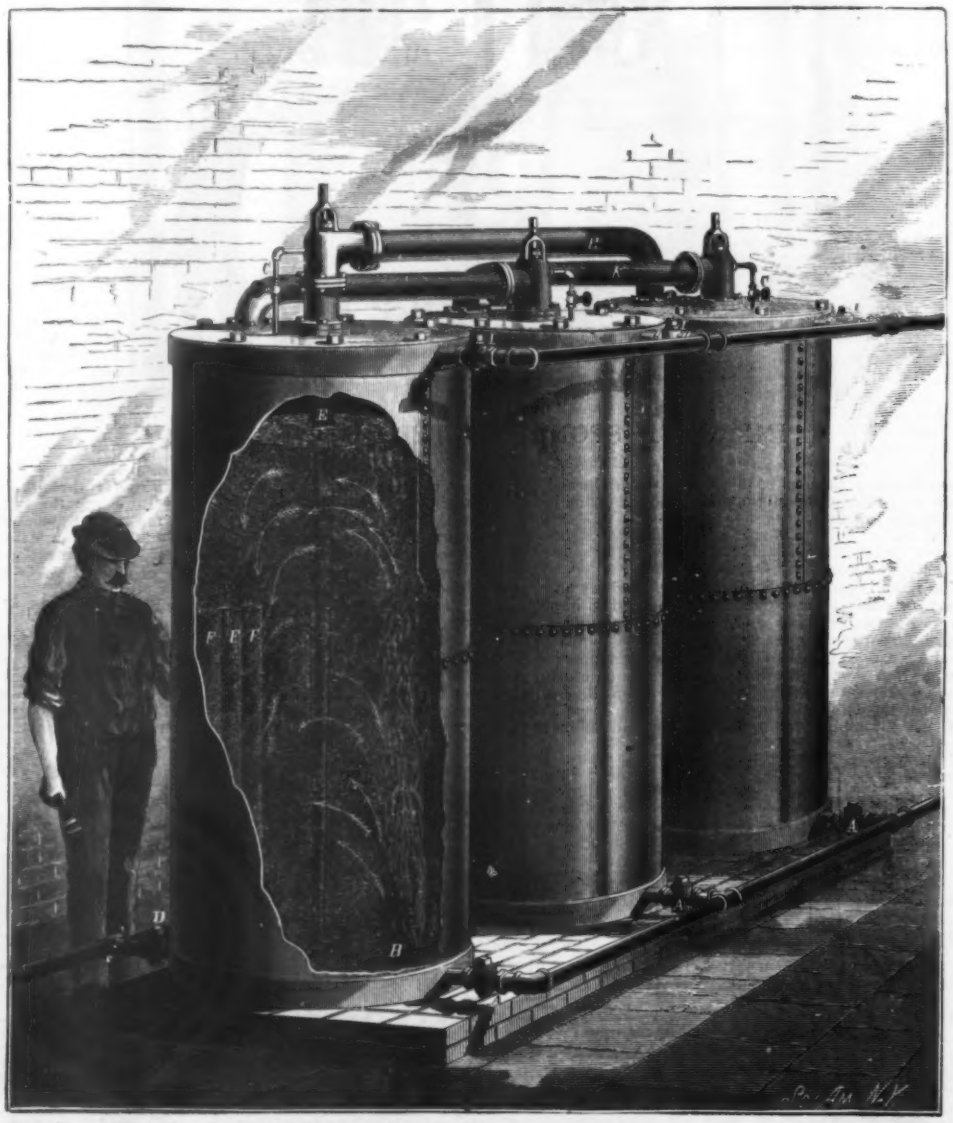
As before mentioned, this style of filter is made in gangs or series of any desired number, one of the series being always employed in rotation for washing the sand.

The Hyatt filter No. 3 differs from No. 2, not in principle but only in construction; the object being to make a single filter complete in itself, both for filtering and washing purposes. In the great majority of cases, where more water is to be filtered than is used in an ordinary house or small steam boiler, the No 3 filter will be recommended. But as it occupies more vertical space than No. 2, some industries having limited vertical space might find No. 2 better adapted to their conditions.

As will be seen in the illustration, filter No. 3 is constructed with two compartments, one above the other. The lower compartment is the filter proper, and the upper one is simply a tank used only during the operation of cleansing the sand. The cut shows a filter eight feet in diameter, and, including both compartments, twenty feet in height. In this size the water is admitted in the center, and passes upward and outward to the circumference of the filter, so that all the water is filtered through four feet of sand.

The operation in this filter is as follows: The water to be filtered is admitted through the valve, B, and, as it is filtered, passes through the perforated screen, C, which surrounds the sand and is supported by the outer shell. Ample room is provided between the screen and the shell for the passage of the filtered water down into the annular space, D, from which it issues through the outlet valve and pipe, E. This arrangement of large filters supplied with water in the center furnishes the greatest possible filtering capacity on a given ground space, and is especially adapted to large industries and to towns and cities.

When the sand in this filter is to be washed, the valve, F, in the head is opened and the outlet valve, E, closed. The water then rises till the upper compartment is filled. Then the valve, F, is closed, and the valve, G, at the top of the pipe, H, is opened. The contents of the filter can then only escape by way of the pipe, H, through its branches, which reach nearly to the bottom of the filter. The pressure of water coming into the filter forces the water and sand in a steady stream up through the pipe, A, and discharges the whole into the upper compartment. Water also coming into the pipe, H, by the aperture, O, under the head, aids the flow of sand upward, and also assists in washing its particles free from the accumulated impurities. The water in the upper receptacle, as it receives the incoming flow, effects a complete separation of the impurities gathered in the sand, and they flow away with the excess of water into the overflow through I, and out through the waste pipe, K. In from



THE HYATT FILTER NO. 2.

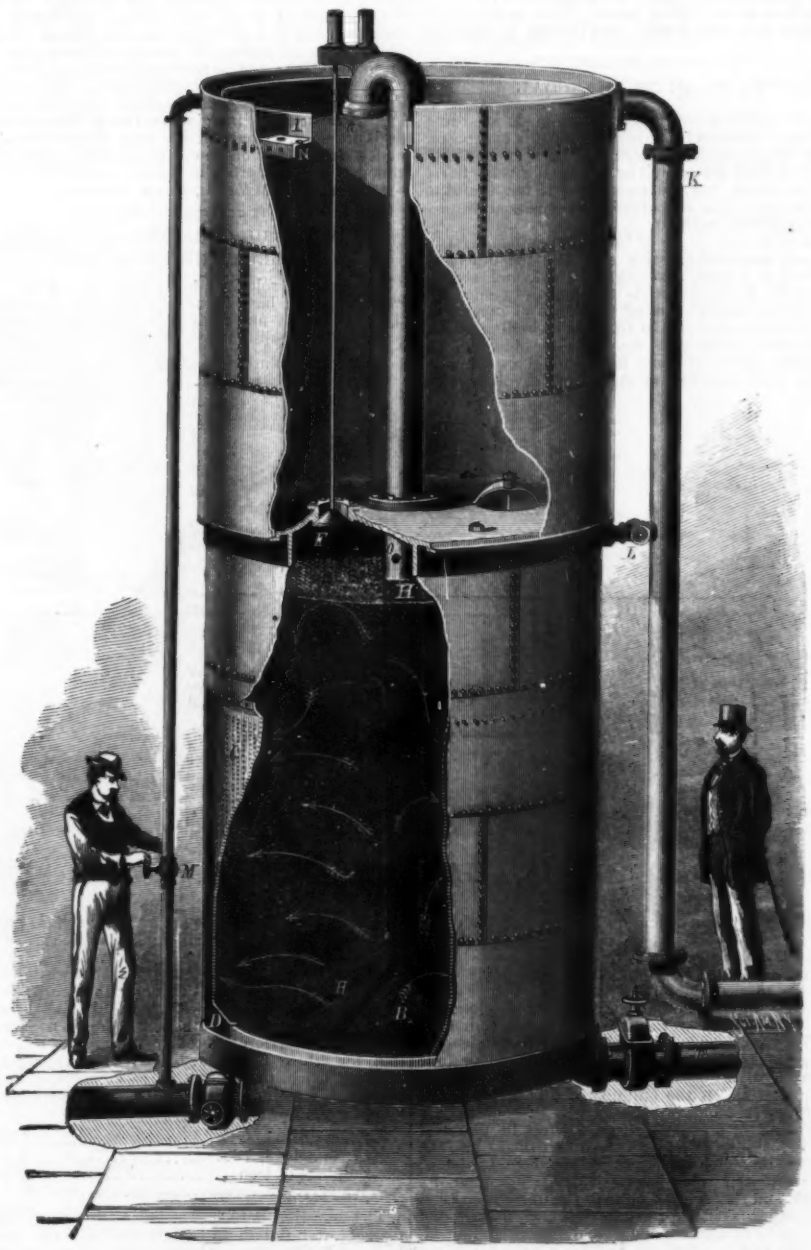
ten to fifteen minutes, according to the supply of water, all of the sand in the filter (about 500 bushels in this size) is discharged and thoroughly cleansed into the upper tank. Now the filter below contains only water. To give it back its sand the supply pipe is closed, the valve, F, in the head, and valve, L, leading to the waste pipe are opened. Immediately the sand and water commence descending through the opening, F, the sand settling and filling the filter, while the excess of water escapes by the waste pipe.

In this operation the sand is washed through the water a second time, and of course is left in a still finer condition for filtration. As the sand is descending, when two-thirds or three fourths thereof have passed through the opening to the filter below, water is admitted into the trough, I, at the top, from which it falls in small streams through the perforations in the bottom of the trough, washing the sand away from the sides of the tank and carrying it all through the opening into the filter underneath, then the valves, F, G, and L, are closed, and filtration resumed.

The largest size of filter (No. 3) is 10 feet in diameter and 20 feet high, having a capacity of 750 bushels of sand, and will filter from 500 to 750 gallons of water per minute. Twenty such filters will purify the water for a city requiring 10,000,000 gallons of water daily, and give a surplus; and the services of one man only would be required to thoroughly wash them once a day. The average waste of water in cleansing the sand in either style of these filters is about one per cent. of the whole amount filtered. These remarks apply to the average water requiring filtration; but a larger percentage of water for washing would be demanded to filter the water in some of the Western rivers, containing large quantities of clay.

In most cases filters above 40 inches in diameter are built entirely of boiler iron, and constructed for high or low pressure, as may be required. They are thoroughly bituminized interiorly, to prevent rusting, and, it is believed, will last as long as the best constructed water mains; and as there is no waste of sand, there is nothing to repair, except the ordinary wear of water valves, thus confining the cost of maintenance to the expense of one man about fifteen minutes a day to do the washing of each filter.

It will be seen that, with these water purifiers, the Newark Filtering Company have the means of filtering river, pond, or lake water in any quantities, large or small, and in all situations and under any pressure required. Whether for house purposes, hotels, steam boilers, manufacturing industries, villages, or cities, they can meet any want, and claim the ability to filter a greater quantity of water, at less cost of installation and maintenance, than can be done by any other known means of mechanical filtration.



HYATT FILTER NO. 3.

LEAD AND TIN IN POTTERY AND GLASS.

APART from the security afforded to manufacturers of pottery by the standing of the firms from whom they receive the various chemical products necessary for their industry, there is no doubt that a knowledge of the normal component parts of such preparations is important to all interested in their purchase. Such an acquaintance with the substances in question not only facilitates the detection of adulteration, but also prevents too exacting repuirements as to the results to be obtained.

In a singularly able series of articles on the above subject, the *Sprechsaal* has summarized the principal facts affecting the manufacture and employment of the chemical preparations of lead and tin now used in the ceramic industry. The abuse of the term *chemically pure* is alluded to as being not only misleading, but also as indicating a degree of freedom from foreign substances which is not really necessary. Thus various preparations if *chemically pure* must inevitably be excluded from general industrial utilization by their high price, and it is remarked that the ceramic industry only requires unadulterated preparations made from the best raw materials. The nature of these raw materials, even under the most favorable circumstances, often renders chemical purity out of the question, and the suggestion is made that the term *technically pure* is more applicable, since it expresses (as is really intended by the other designation) that the preparations to which it refers are free from intentional adulterations in the process of their manufacture.

In the instance of white lead, the special requirements of the ceramic industry have to be borne in mind by the manufacturer, and the admixture of chalk, heavy-spar, etc., which is a recognized custom in the preparation of the article for paints, etc., must necessarily be omitted, as the consequences are serious should an adulterated substance be employed. The presence of other metals in the lead used is specially to be avoided, and consequently none but the best refined lead should be employed. If white lead enters in a large proportion into a glaze, the admixture of iron and copper (even in a very small proportion) is apt to produce tinges which may be erroneously ascribed to the other components of the glaze or to the substances used in the ware itself.

The preparation of white lead by the French process is considered more suitable for an article intended to be used in the ceramic industry than its manufacture on the dry system, which is now in general use. The impurities which the latter method allows to pass into the white lead are eliminated in the liquid process, in consequence of their not being dissolved by the acetic preparations employed.

At one time white-flake was much used by stoneware manufacturers in their glazes, and as it was delivered in an unground form, the consequent facility of detecting adulteration obtained for it a certain preference, but it is stated that this circumstance is now of little importance, as unadulterated white lead can always be obtained if it is specially ordered. White of silver was at one time a singularly pure article made from Villach lead. It is remarked, however, that wares, more or less mixed, are now sold under this name, although it can of course be obtained, if required, in a condition of relative purity from Austrian manufacturers. Similar remarks are applied to other preparations, such as Hamburg white, pearl white, and Venetian white.

When intended for the object indicated, red lead must be as free as possible from natural impurities, and must contain none of the admixtures which are met with in low grades intended for other purposes. In colored glazes which contain a relatively large proportion of lead (as well as in muffle-glazes), the process of manufacture is seriously deranged if there are present metallic oxide-silicates, oxide of antimony, or like substances, which are difficult to melt. The frequent adulteration of red lead has caused the adoption of orange-mine for delicate work, but it is remarked that in colored glazes for earthenware, etc., ordinary unadulterated red lead can be used.

Preference is, however, given to the so-called *crystal red lead* (which is made from the best refined lead), if in the composition there are relatively large quantities of coloring metallic oxides or of oxide of tin.

In litharge purity cannot be expected, and all that can be required is for it to be delivered as it comes from the lead works, without any admixture with other substances. Commercial usage not having authorized the practice, it is remarked that any such admixture of chalk, etc., must be regarded as an intentional adulteration. Lead-ash is usually made in Germany by pottery manufacturers themselves, and requires lead of the best quality.

Potter's ore (or alquifou), as usually delivered to the ceramic industry, is a coarsely-ground sulphuret of lead. In its pure state it is composed of eighty-six parts of lead and fourteen of sulphur. In its employment 100 parts of this substance represent the action of ninety-three parts of the best litharge or ninety-six parts of red lead. The best descriptions (which contain eighty-four to eighty-six per cent. of lead) are, however, largely used for the extraction of that metal, and the description which pottery manufacturers usually receive is more or less mixed with copper, zinc, antimony, arsenic, and silver, as well as with small quantities of certain sulpho-metals, besides the sulphuret of lead to which reference has been made. This substance, it is stated, is appreciated by the ceramic industry, and stress is laid upon the necessity of obtaining such qualities as present but little variation in their percentage of lead. It is considered that the eighty-five per cent. quality is for many reasons the most advantageous to use, and with a view of preventing any practices of adulteration being carried on, it is suggested that samples of the article should, from time to time, be sent for analysis to one of the public offices devoted to that purpose, it being difficult for non-professional persons to carry out the somewhat complicated experiments necessary for defining the purity of preparations of lead.

Some articles are, however, usually to be found exempt from adulteration, such as orange-mine and the fine qualities of massicot. The lower qualities of the latter substance are, however, said to be often little else than finely-ground litharge.

The chief preparations of tin used in pottery manufacture are white oxide of tin, amorphous oxide of tin, and tin-putty. The amorphous oxide is a powdered, white, anhydrous substance, and tin-putty is now an article produced for sale, whereas the older faience manufacturers used to prepare it for their own use. These articles can, without difficulty, be produced in a condition of purity quite sufficient for the requirements of ceramic manufacture, yet they are often met with in a more or less impure form. This is attributed less to intentional adulteration by the makers than to want of care or insufficiency of chemical knowledge on their part.

As in the instance of lead, the best qualities of tin must be used for the purposes indicated. The descriptions considered most suitable are Banca, Billiton, and Malacca, as well as English grain tin, these qualities being almost free from metallic impurities. This is less the case with English block tin, and with the kinds produced from German ore, which contain admixtures of other metals to such an extent as to be unsuitable for use in the ceramic industry.

White oxide of tin is produced by the oxidation of tin with nitric acid. It is of a pure white color; but this fact is no evidence of its purity, as it may still, under these circumstances, be adulterated to the extent of several parts in a hundred. The nitric acid used must only contain traces of muriatic acid, as this latter agent produces oxidation in another form, which is in some cases detrimental to the subsequent industrial processes in which the oxide of tin is employed. The removal of the excess of nitric acid requires care, special precautions being necessary as to the water used, inasmuch as spring water sometimes contains substances capable of deranging the processes which follow. Soda is sometimes employed in connection with the removal of the nitric acid; but this practice is disapproved, as well as the employment of milk of lime, which sometimes has been found to result in the oxide of tin containing 10 per cent. of lime and carbonate of lime, which cannot have been introduced in any other way. From the above grounds the use of suitable water for washing the oxide of tin is alone recommended.

A fertile source of impurities in the substance referred to is the melting of the tin in iron vessels, on account of the heat to which the iron is brought, and the length of time the tin is in contact with it. Thus the purest tin, after being washed in the most careful way, may, after calcination, produce red oxide, on account of the presence of iron. In order to avoid this occurrence, it is necessary to employ plumbago crucibles in melting the tin. The oxide of tin contains a certain quantity of water. It is difficult to bring it down to the natural limit of 11 per cent., and provided it does not exceed 18 to 20 per cent. no serious inconvenience results. It is suggested that manufacturers of the article should be required to delivered it with a maximum of 20 per cent. of water.

Oxide of tin loses at red heat the whole of its water, and then appears of a pale yellowish straw-color. Should it appear, after calcination, of a deeper yellow, reddish, greenish, or gray tinge, it contains inadmissible impurities, arising either from the employment of inferior qualities of tin or from unskillful treatment. If a powdered oxide of tin has baked together, it is a proof of its faulty preparation. Experiments made have failed to produce (with the nitric acid treatment) an oxide of tin which would be perfectly white after calcination, even when the best Banca tin and distilled water have been employed. It is, however, remarked that

by using Banca tin a very light straw-colored product is obtained after calcination. In the instance referred to there had remained in the hydrate after the washing a certain quantity of the nitric acid, which disappeared in the calcination. It is suggested that the sale of the article in its calcined state would, for many reasons, be preferable to its being delivered in the hydrate form, as the expense of the complete elimination of the nitric acid would be avoided, and no discussion could arise as to the proportion of water contained. An instance is quoted of adulteration to a serious extent having been found in oxide of tin of pure white color, and described as being *chemically pure*.

Amorphous oxide of tin has been, it is stated, for some years an article of commerce. It is an anhydrous oxide in a powder, remaining loose and white after calcination. It is said to be prepared, most likely, by a dry process. The writter of the description given has not made any practical tests of its suitability to ceramic manufacture, but considers it worthy of being tried, as from its being in powder its employment should be relatively easy, and its freedom from water should render its action more reliable. It is said to be offered at the same price as the white oxide, containing 20 per cent. of water, and, it is remarked, ought therefore to be more economical in use to that extent.

Tin-putty is known to consist of a mixture of lead and tin, the proportion of the latter not usually exceeding 50 per cent In the manufacture of tin enamels (whether colors or glazes) tin-putty has, it is said, decided advantages over oxide of tin, as it contains oxide of lead and oxide of tin in molecular decomposition. If the tin-putty is melted together with silicic acid or boracic acid, the oxide of lead is dissolved, and the molecules of oxide of tin are divided in the most uniform manner between the particles of the silicate of lead which has been produced. This circumstance is thought to be of importance in the production of a good enamel. It is remarked that the melting together of oxide of lead and silicic acid in combination with ordinary oxide of tin would not so easily produce a good enamel. The reason given is that the silicate of lead, instead of being opposed to the molecules of oxide of tin, would have to act on grains only susceptible of gradual dissolution, it being thus required to increase the degree of heat, and to lengthen the duration of the process. This necessity produces various inconvenient results, such as the excessive quantity of substance which light-flowing enamels dissolve from the material of the crucible itself, and the separation of salt in the instance of salt enamels.

The employment of ordinary oxide of tin in the preparation of enamels is said to be still more disadvantageous if it is only ground together with the lead. If it is from any cause found desirable to use oxide of tin instead of tin-putty it is argued that amorphous oxide is preferable to that made with nitric acid. It is also stated that tin-putty is the cheapest form of oxide of tin, air being the oxidizing agent, and the expense of production being therefore unimportant. The remarks previously made as to the importance of pure metals being used are likewise applicable to the preparation of tin-putty. Care must also be taken to prevent the substance receiving any impurities during the process of its manufacture, particularly by avoiding the German custom of using iron vessels for that purpose. Furnaces of fire-proof slabs, or muffle appliances similarly constructed, are recommended. It is not easy to detect impurities in the article as usually delivered, and if such admixtures are suspected, it is remarked that a regular chemical analysis ought to be made.—*Pottery Gazette.*

CERAMIC COLORS.

THE revival of taste for art in connection with industry has caused renewed attention to be given to the question of coloring, and this has been the case as regards the ceramic industry in a relatively important degree. The application of colors to majolica has been on an extensive scale; but, with reference to this subject, it is remarked that by majolica are usually understood all kinds of glazed ware in various colors, whether the color be produced by colored glazes, by a colored substance, by colored decoration under the glaze, or upon faience glaze, and stoneware glaze, etc. Still the authorities upon the technicalities of the ceramic industry prefer to confine the name majolica to those porous products which are covered with a colored glaze of one or more colors. These last named manufactures might, according to Dr. Schumacher, be called modern majolica, in contrast to the colored faiences, for which, in various circles, the designations of majolica and Italian majolica have been retained. Faience he understands to be the product of oxide of tin enamel glazes.

In an able review of the progress of ceramic coloring, in the *Thonindustrie Zeitung*, Dr. Schumacher remarks that the majolica productions now offered for sale give evidence of considerable progress. He adds that many German and Austrian manufacturers produce very effective work, as far as a command of color and glaze is concerned; but there is, in many cases, a want of brilliancy in the glaze, while the scale of colors is often of limited compass. He attributes the last-named appearances to an unsuitable composition of the material itself, together with deficient knowledge of the effects of various coloring substances, as well as to the use of the decorative methods of stoneware manufacture under inappropriate circumstances. He suggests that, for the general spread of a rational system of majolica production, it is necessary to study the coloring metallic oxides, and in a particular manner the ceramic chromogenes, or color-producing substances, in their relations to the glass fluxes used as glazes. The object of his remark is the diffusion of information on this subject; the facts quoted resulting from practical work, and not being merely the outcome of special technical investigations.

The color and tints which a color-producing substance gives in glass fluxes are practically dependent upon various circumstances:

1. Upon the composition of the glass flux itself. 2. Upon various special component parts of the glass flux. 3. Upon the temperature. 4 Upon the color of the body.

As to the first point, a distinction may be made of glass fluxes containing alkali in relatively large proportion, silicate glass fluxes in which alkali silicates preponderate over oxide of lead silicates, or where the latter are absent; (2) glass fluxes containing lead or oxide of lead, with an excess of those substances as compared with alkalies, or the latter being absent; (3) glass fluxes containing alumina, in which, besides other glass-forming substances, silicate of alumina exists in such quantity as to alter the effects of the alkali or lead; (4) boracic acid glass fluxes into which a considerable proportion of boracic acid or borax acid has entered. It is remarked that lime, as a component part of a glaze, appears to be neutral against the effects of chromogenes—that is to say, it is not affected by alkali and lead, though it is said to be partially influenced by baryta.

Among the special component parts of glass fluxes capable of affecting chromogenes are oxide of tin, oxide of antimony, phosphate of lime, oxide of zinc, and also alumina, which does not attain a silicate formation, or, at least, a high degree of silicic acid combination. The three first-named substances specially affect the glass fluxes by giving them an opaqueness which bleaches most colors.

The influence exercised by the temperature may be readily observed if a copper-azure glaze be placed in a muffle-furnace (at perhaps 1,600° to 1,800° Fahrenheit), and another time in a stoneware glazing furnace. In the former it acquires a beautiful azure blue, and in the latter a poor shade of green. Chromic acid gives yellow in majolica glass fluxes, but in a stoneware glaze fire it produces green. The effects in the latter case are attributed to the change in the constitution of the glaze, brought about by the dissolving of the substance of the body.

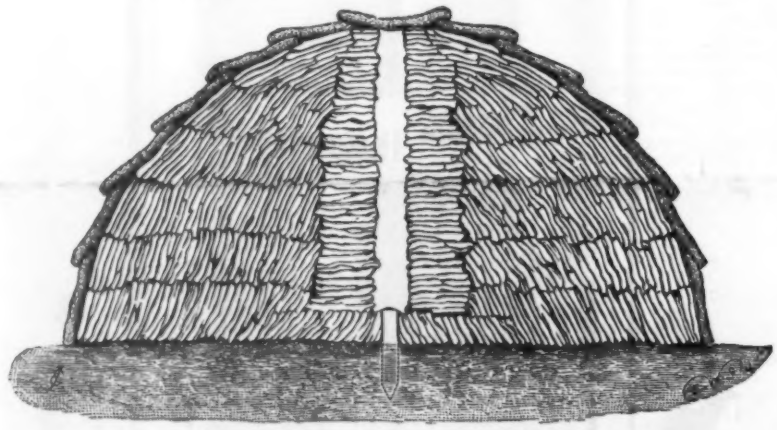
As to the color of the body, this has of course an effect in the instance of transparent glass fluxes, a mixed color being thus produced by the co-operation of the glaze color.

The subsequent remarks of Dr. Schumacher deal with the particular effects of oxide of lead, oxide of iron, oxide of manganese, oxide of chromium, chromic acid, oxide of uranium, protoxides of nickel, cobalt, and copper, oxide of copper, etc. He remarks that the precious metals are scarcely ever used for glaze coloring, their use being limited to vitrifiable pigments—gold producing purple, silver an uncertain yellow, platinum a beautiful gray, and iridium an effective black.

MANUFACTURE OF CHARCOAL.

INQUIRIES having been from time to time made regarding the production of charcoal for gardening and other purposes, the following simple method, which has been successfully carried out on a large estate, and by which the very finest charcoal is produced, may be interesting if not useful to some of our readers. As now conducted, charcoal is prepared by two different methods.

One is that of placing the wood in an iron cylinder, set in brickwork, and surrounding with fire; and the other, by piling the wood in a heap, covering with turf, and setting on fire; but as the latter method is that generally adopted, we purpose giving a description of the mode of operation. Select a piece of ground sheltered from the prevailing winds, and to which easy access with wood can be obtained. A hut or temporary shelter of some kind should also be provided for the men engaged at the work, as during the period of burning constant attention is required, both day and night.



A CHARCOAL PIT.

The quality of wood used is not of special importance, although charcoal produced from ash, oak, or beech is of superior quality to that obtained from most other woods, and may consist of firewood, or any unsalable pieces of timber that may be come across in the general course of thinning. The wood is sawed into pieces two feet in length, and these again split if required to about three or four inches square, until a sufficient quantity has been cut up for the pit, after which the building of this is proceeded with in the following manner:

The pit is made of a conical shape, 21 feet in diameter and 9 feet in height. A strong stake is driven into the ground, the top of which is left protruding about 12 inches; around this are placed small pieces of dry ash or pine of a similar length, and standing as close to the upright stake as possible. Another layer is formed in the same manner, and so on until a circle of about four feet in diameter is obtained. A circle of one foot in diameter, and having the top of the stake formerly driven into the ground as center, is next made by placing the wood horizontally side by side on the upright pieces, laying others on these in a similar manner until the pit is of the required height, thus forming a sort of chimney, by means of which the pit is fired; the wood used here being dry pieces of ash 24 inches in length, but split rather smaller than the ordinary pieces. Outside this the wood is placed on end and reclining inward, this being continued until the pit is of the required size.

The top half of the pit is now carefully examined, and any crevices between the wood are packed full of small pieces of turf and sawdust to exclude the air. The pit is then covered with newly cut turf, beginning at the base and working toward the top, each row of turf overlapping by a few inches the previous one, the circular hole or chimney being left open for firing. The best turf for this purpose is that grown on loamy soil, that from clay being too stiff, and leaving a residue after burning of clods instead of fine soil.

The turf may be cut any convenient length, but not over a foot in width, the quantity required being about three loads. The pit is next fired by dropping a quantity of burning wood and some dry pieces of pine or ash into the opening left at the top. After having become thoroughly lighted the top turf is put on, which completely shuts up the chimney, when the process of charring commences.

During the period of burning constant attention is required day and night, more especially should the weather be stormy, for the wind blowing for some time from one point generally causes that side to burn very rapidly and "flat" into a hole; should this occur the hole must be at once filled with knotty logs, which should be laid aside for this purpose when splitting the wood, and recovered with turf, any crevices being carefully filled with sawdust to exclude the air. During mild weather less attention is required; the pit burns uniformly all over, and produces the best charcoal.

The time required in burning varies from seven to nine days, much depending on the state of the weather, mild requiring the longest period. As the charring proceeds the turf gradually disappears, until only a slight covering of burnt earth remains, at which point the pit is reduced to about half its original size. When cool the pit is ready for being opened, the charcoal being extracted by means of a light rake resembling a drag, but with much finer teeth; and after becoming thoroughly cool, is stored in a dry shed, until required for use. By the above method the very finest charcoal is produced, and of superior quality to what is generally sold. The accompanying illustration represents a section of charcoal pit ready for firing.

Properties and Uses of Charcoal.—The principal use of charcoal is for combustion, for which purpose it is found not only cleaner to use, but also productive of greater and more lasting heat than most other combustible matters, and therefore it is of inestimable value for cooking purposes.

Great care should be exercised in the using of charcoal, as during its combustion carbonic acid is formed by the union of the oxygen of the air with carbon, which acts upon the human system as a powerful sedative poison. It is of frequent use in the garden for potting purposes, vine borders, flower beds, etc., and in the transmission of bulbs nothing is better for packing than charcoal dust. The consumption of charcoal for gunpowder making is also very great, preference, however, being given to that produced from certain kinds of wood. Charcoal is a good disinfectant, tasteless, inodorous, and full of pores, nearly 100 inches of gaseous ammonia being absorbed by a cubic inch of fresh charcoal. —*A. D. Webster, in the Gardeners' Chronicle.*

NEW USEFUL CLEARING SOLUTIONS FOR GELATINE NEGATIVES.

FOR clearing solutions to be used after fixing, says the *Photo. News*, we have found that of all the various mixtures of alum solution and acids which have been proposed, few give a better result than the following·

Saturated solution of alum	1 pint.
Hydrochloric acid	1 ounce.

This mixture appears to act quite as well as one in which the hydrochloric acid is replaced by citric acid, while it has the advantage of being much cheaper.

This acid solution, like all others that we have tried, has the property of somewhat reducing the density of the negatives which are treated with it. This may be a great advantage at times, but at others it is the very reverse.

Mr. B. J. Edwards recently introduced a clearing solution, for which he claimed that, while it gave a favorable printing color to a negative, it in no way reduced the density. The solution which Mr. Edwards recommends is mixed as follows:

Alum	1 ounce.
Citric acid	1 "
Sulphate of iron	3 ounces.
Water	20 "

The negative it to be treated with this solution immediately after fixing, and slight rinsing under the tap; that is to say, the hyposulphite of soda is not to be entirely washed away.

We have recently been using this solution, and find that, applied as Mr. Edwards directs, it leaves nothing to be desired. Used in place of the ordinary acid clearing solution as the latter often is—that is to say, on a negative which has been fixed, thoroughly washed, and possibly dried—it appears to have little advantage over the older method.

We have also been more successful in performing silver intensifications with this solution than with any other which we have tried. The negative to be intensified is *thoroughly* washed to get rid of all hypo; it is then placed for some minutes in the solution, the formula for which we have just given, and afterward flowed with a small quantity of the same solution, into which has been dropped a little of a twenty-grain solution of silver nitrate.

If the negatives to be intensified be quite clear in the shadows, we have found no difficulty in intensifying them in this manner up to any desired extent. But if they be even a little fogged we have found great difficulty, as, in such a case, the shadows appear to intensify almost as much as the high-lights.

There is a stain quite different in nature from the ordinary pyro stain, which, although it resembles it somewhat in appearance, is in reality a much more objectionable phenomenon. It usually comes when a negative has been imperfectly fixed—when, perhaps, all the visible bromide of silver has been dissolved away, but when there has still been left in the film a certain portion of some silver com-

pound. The color is not evident at first, but comes on after the negative has been exposed to the light and air for a few days. It is rather a fog than a stain. A stain covers a negative as well in the denser as in the more transparent parts, although it may be most visible in the latter, and therefore has no effect but to make it somewhat slower in printing. A fog, such as the one in question, appears to attack the shadows only, or at least more strongly than it does the high-lights, and thus, reducing the contrast, ruins the negative.

The ordinary yellow pyro stain is generally pretty evenly distributed over the film. The fog which we mention is usually confined to one portion, namely, the one which has been the last to fix. For this reason it is more detrimental than it would otherwise be.

It is not acted upon by either citric acid and alum, or hydrochloric acid and alum. We have, however, found that it will generally give way to a solution prepared as follows:

Saturated solution of alum	1 pint.
Nitric acid " " "	1 ounce.

THE COLOR BLUE IN BUILDING MATERIALS.

BESIDES the invaluable use of blue as a pigment, to which allusion is made further on, this color plays a more important part than many suppose in giving a distinctive hue or character to building materials, there being scarcely one in general use to some variety of which it does not lend a title or impart a decided tint or tone. In some cases a blue tinge is a token for good, as when gray cast iron shows in fraction numerous shiny bluish-white specks. In others it savors of mischief, as when it colors sapwood or unprotected shale. In frequent instances, however, the presence either of a shade or cast of blue merely affects the aspect of materials, and is otherwise inconsequential, though upon the mode of applying or combining them will depend all the difference between cheerless monotony and the charm of an agreeable contrast. Nothing, perhaps, appears so dull and bald as a lead-covered dome or slope destitute of ornamental treatment; yet it may be made to look really beautiful if set over stonework and adorned with graceful fleches, elegant dormers, and ox-eyes, bold roll jointing, either straight or zigzag, and fanciful cresting.

SUGGESTIONS IN ARCHITECTURE.—THE GARDENER'S COTTAGE AT BELRATH BURY, KELLS, ENG.

BLUE IN BUILDING STONE.

Blue tints of almost any degree of intensity are to be found in the quarries of the United Kingdom, there being thirty or more from which are raised dark blue, blue, light blue, bluish, and bluish-gray sandstones, limestones, and granites. As a rule these are as serviceable as those of any other color, when the proper precautions as to seasoning, selection, and bedding are observed. Blue sandstone is usually found at the bottom of a quarry, or at a part which was formerly the bottom, and liable to be flooded with standing water; and the color is probably attributable to the soakage or percolation of water saturated with the bluish matter of some adjacent shale, which at a remote period was itself colored by the iron salts of decomposing rocks, or through the medium of bituminous matter. Limestones and marbles are found in such profuse diversification as to color, texture, or figuring, through contamination with ferruginous, argillaceous, and organic matter, while granites mostly owe their bluish and other tints to the feldspar which forms their predominating constituent. Some splendid Merrivale granite is decidedly bluish. A fine clear blue also distinguishes a close-grained granite drawn from Cairngall quarry, Aberdeenshire, where blue granites abound. These admit of being wrought into mouldings, balusters, slabs, and columns, which take a fine polish, and are suitable for external decoration. Blue wynn is a Scotch term for any hard, bluish, compact stone fit for paving, and most blue granites answer well for curbing, pitching, pavements, and trams. Ireland is rich in blue limestones, the darker colored varieties being, however, difficult to work, whereas the lighter kinds are easily hewn. Forest of Dean sandstone, and the limestone from Sparkford quarry, Dorsetshire, are good English samples of blue stone used in building and engineering. The Yorkshire quarries of Appleton, Well Hill, Banks, Oulton, Brighouse, Morley, Boltonwood, Robinhood, Idle, Gazeby, Eccleshill, etc., yield an abundant supply of sandstone, either of a decided blue color, or else blue in comparison with the whiter and browner varieties; and from their produce may be selected stone applicable to any purpose, from a dripstone termination to an engine bed. Among the marbles which are so highly esteemed and appropriate for internal decoration, blue is a rare color, Derbyshire and Sutherlandshire probably alone producing it in Great Britain, though purplish marble is not uncommon in some Irish quarries.

BLUE IN BRICKS, BRICK EARTH, ETC.

Blue clay and blue shale, when protected from the weather, make a good foundation bottom, but the latter is treacherous to a degree if left exposed to it, and quickly changes, as more than one contractor has found to his cost, from a hard rock into mud and sludge. Perhaps the most obnoxious position in which blue clay occurs is when found filling up holes in unsound blocks of white Mansfield and other stones. As used in brickmaking, the stiff and tenacious dark blue clay, such as some of the Gault clay underlying the chalk, loses its color in burning, and yields whitish bricks flushed with pink patches. An ordinary clay containing alkalies will, however, produce bluish green bricks when subjected to sharp and hot firing. Genuine blue bricks—for bricks are not unfrequently painted blue in gauged arches and elsewhere—are made chiefly in Staffordshire, and are obtained by firing or burning clay containing from eight to ten per cent. of peroxide of iron with sufficiently sharp heat to turn the peroxide into the black or magnetic oxide, which combines with the silica, and fuses. The vitrification renders these bricks very hard, dense, and durable, and they leave the oven imbued with a dark blue or black color, the terms black and blue being just as convertible among builders with respect to bricks and mortar as blue and gray are in their application to stone. Other blue ware, such as quarries, roofing tiles, ridging, and so forth, is similarly prepared. Single courses or bands of sound, hard, blue bricks laid in cement form effective sill, lintel, string, or bond courses in a red or white brick wall where the roof is covered with blue slates. Blue headers are bricks otherwise called glazed headers, from a bluish gray glaze given to one end by placing salt round it in the kiln previous to lighting up. Artificially stained bricks of a rich chocolate color, lighter, however, within than without, are sold as blue or black bricks. Most descriptions of plain, ornamental, and glazed tiles are manufactured in blue as well as in other colors, and so are tesseræ and enameled bricks, of which those denominated turquoise form an elegant variety.

BLUE IN SLATING.

The great majority of roofing slates are either dark blue, blue, purple, bluish gray, or bluish black, though there are equally good gray and green ones, the color not being of so much importance as its uniformity, both as regards each slate and the entire covering. A slaty color nevertheless always conveys the idea of one containing a strong infusion of dark blue unassociated with the other primaries.

BLUE IN WOOD.

Blue wood is sapwood of a bluish color, and though much of this unsound timber is often difficult to distinguish, it is not always so, and particularly when the descending sap thus conspicuously marks it. Some kinds of wrought fir palpably disclose its whereabouts, but white fir, commonly called white deal, which takes a bluish tint on exposure to the weather, does not betray any distinction between the heart-wood and sapwood. Soft and rapidly decaying blue wood is not allowable in first and second quality floor boards, but inferior kinds may contain it *ad libitum*. Listed boards are those from which the sap has been removed by narrowing them down, and it would no doubt be a fortunate circumstance if the common practice of priming joiner's work could equally well eliminate the sapwood instead of offering facilities for its concealment. The blue marks occurring in oak from sap may be removed by means of a strong solution of sulphate of zinc, which must not be allowed to remain on after the blue disappears.

BLUE IN CEMENT, MORTAR, LIMESTONE, SAND, ETC.

Passing on to mortar and cement, it will be found that good, neat Portland cement ought to exhibit a bluish gray color at the time of setting. It changes afterward to a lighter gray. Greenish gray or gray is recognized as the proper color for the powder before adding water, whereas under the same circumstances bluish gray would indicate a "blowing" sample, particularly if the powder happened to be coarse.

The well known blue lias lime is obtained from stone belonging to the lias formation, and is so named from the dark blue color of the raw stone, which assumes different shades of buff or pale gray when calcined. It is a hydraulic line, varying, however, considerably in its degree of hydraulicity, owing to the stone containing widely different proportions of carbonate of lime, silicate of alumina, and sand, and consequently, in important works under water or in moist localities, none should be used without testing. When in lump, and not ground, it slakes very tardily, and it is not a favorite with workmen accustomed to gray chalk lime, otherwise "stone" lime, on account of the trouble requisite to slake it properly. Ground lias not only contains the core incorporated with it, which renders it inferior to the lime in lump, but it often consists of the commoner and softer varieties, and is further open to adulteration, and to get stale in the sacks or bags. For external plastering blue lias is likewise not in favor; for, though the material is cheap enough, the labor required, on account of its slow setting, makes it expensive, and it has therefore not stood its ground against Portland cement. The quantity of sand it will bear is of course dependent on the quality of the materials; but 2 of sand to 1 of lime is a good general formula. A capital concrete results from a mixture of Portland cement, blue lias, and aggregate in the relative proportion of 1, 2, and 21. Blue mortar is mortar darkened by ironfounder's sand or mineral or vegetable black, or it is sometimes composed of 4 parts of blacksmith's ashes sifted fine to 1 of Portland cement, or of three parts of the ashes to 1 of blue lias. Another variety is compounded of 2 parts of smith's ashes, 3 of slaked lime, and 4 of sand, and this, it is said, is impervious to rain or damp. Blue pointing is another name for black pointing, and consists in pointing slater's, bricklayer's, and mason's work with blue mortar. Slaters, however, often enough use common oil putty, and paint it black or dark blue. Rubble masonry is sometimes capable of being much improved by pointing with a neatly trimmed raised joint in blue mortar; and white brickwork likewise, but in both cases it must be well done, or it will soon split off.

BLUE IN WINDOW GLASS.

White window glass mostly shows a greenish tint, although oxide of cobalt is used in small quantities to correct the color, but on the other hand when applied plentifully it produces a brilliant blue pot metal, or flashed or painted glass, according to its mode of application. Enameled glass, glass mosaic, and other kinds of ornamented and tinted glass contain their fair share of blues.

BLUE IN BUILDING METALS.

An examination of the metals shows that blue is obviously present in zinc and lead, while it can be more or less easily detected in some kinds of iron and steel. Pure zinc is bluish-white, and when tarnished by exposure to the air becomes coated with a whitish film of oxide, and partakes a little of a grayish cast. This coating impedes further corrosion by the atmosphere when uncontaminated with acids. Galvanized iron presents much the same appearance as zinc, being simply iron enveloped therewith. Lead is likewise bluish-white when pure, but exposure to the air covers it with a gray film of suboxide. Thus both these metals—which are so extensively used by builders for roofing, spouting, piping, tubing, cisterns, and numerous other purposes—are fundamentally bluish, and this character the air only exteriorly modifies and but partially hides. Pure iron is never met with out of the laboratory. It is white in color, and perfect in color and perfect in luster, but its whiteness is not so faultless as that of pure silver. All the varieties of the iron of commerce are more or less grayish, the best descriptions of gray cast iron having bluish-white crystals in abundance, while the white kinds possess a more silvery hue. It is likewise a fact that the best steel, namely cast steel, shows in fracture a slaty gray tint, and here, therefore, there is satisfactory evidence that iron in its best form, which steel has been defined to be, tends toward a bluish color. Much iron and steel is also artificially colored blue by the processes known as bluing in the one case and tempering in the other. A blue tempering color is imparted to hardened steel by gradually reheating it to a temperature of about 580 degs. Fahr., but the exact degree varies with the intensity of the color and the particular kind or quality of steel that is being tempered. Bluing iron tacks and other articles is differently performed, a varnish even being sometimes substituted for the firing process. Bolts and iron fastenings acquire toughness as well as immunity to a certain extent against oxidation by being heated by a blue heat and immersed forthwith in raw linseed oil.

BLUE IN PAINTING, PAPERHANGING, AND DECORATING.

In decoration many happy effects are produced by a wise use of blue. It contrasts with white or buff or orange, when deep with pink or maroon or golden brown, and when bright with chocolate. A light blue pattern on a dark blue ground subdued, lightened, or relieved with fanciful devices in the various tints just enumerated, may be made to result in a very handsome ornamentation to a wall, ceiling, or soffit, where there is a redundance of light; but being cold and retiring, blue requires the adroit and kindly help of the artist to extract from it its intrinsic qualities. Many varieties of blue are used by the decorator. Blue verditer is a beautiful light blue pigment, supposed to be a carbonate of copper, and very useful in distemper painting. Oxide of cobalt communicates a magnificient blue color to glass, and smalt, which is used as a pigment, consists of glass colored by cobalt. Blue ocher is an earthly phosphate of iron, producing a deep blue pigment of considerable use, and not affected by mixture or foul gases. Prussian blue and indigo are almost too well known to require naming. By means of these and similar pigments, not only is decoration in its loftiest sense carried to a successful climax, but the clever marbler is able to compensate in some degree for the dearth of the valuable stones he often imitates on wood, plaster, glass, or slate, with much truthfulness as to figure, color, curl, and vein. From the fantastic and ever-varying pattern displayed by the original mineral, however, there is always a fine field for the imagination to revel in when counterfeiting it, and accordingly, in marbling a blue variety, little else is needed but to

skillfully overspread on a light blue and white ground yellow, brown, ruby, white, or blue in dabs, patches, blotches, spots, and veinings. Blue and gold marble requires in addition a touch or two of gold paint. The paperhanger ably supplements the efforts of the painter and marbler in hiding the nakedness of walls by covering annually acres of surface with pretty blue veined "siennas" and blue "granites," often jointed in ways more picturesque than possible, to say nothing of the satin, pulp, and flock papers, which in their inexhaustible diversity of coloring necessarily exhibit every conceivable depth and tint of blue. Thus it is seen that, although in the decorator's craft blue merely stands on an equality with the other principal colors, most kinds of building materials are, as it were, figuratively connected by a "thread of blue" that has no parallelism in point of continuity in any other color.—*Building Times.*

ROOF COVERINGS.*

IN covering buildings for the purpose of preserving them from the weather, the climatic conditions of the locality must always be considered. The first thing to be determined is the pitch or inclination to the horizon to be given to the roof. In hot climates, where rain is not frequent but falls in torrents when it occurs, a flat pitch is desirable in order to check the velocity of the rain-water which runs down the roof; but in cold countries, where much snow falls during the winter, the pitch should be steep that the snow may easily slide off as it accumulates, and thus prevent damage to the framework of the roof from the superincumbent weight. An ingenious table has been drawn up showing the increase of pitch that should be given to a roof for every degree of latitude north or south of the equator; but such a table can only be of general application. Several different kinds of materials are in use for forming the outside covering of roofs, and their suitability depends largely upon the pitch, some materials, such as copper or lead, being used with perfect safety at a very low inclination or even quite flat, while others, such as thatch, should never be used at a less slope than 45°. Some materials that were formerly used for roofing have now become quite obsolete; for instance, it is very rare indeed now to find roofs covered with shingles or shides, which were small wedge-shaped pieces of wood about an inch thick at one end, and measuring nine inches by five inches, closely resembling weather boarding; these were extensively used in some country districts. Again, in Shropshire, Gloucestershire, and other places, thin flags, called tile stones, were frequently used for roofs, but the facilities of transport are now so great that these have been entirely superseded by the more suitable Welsh slates, or artificial tiles, the manufacture of which has greatly increased and improved of late years. Good roofing materials can now be obtained so cheaply that there is little temptation to builders to supply inferior kinds, and the cause of bad and leaky roofs is to be sought for more in the carelessness or ignorance of the workmen than in the badness of the materials.

By far the most important roofing material, and the one in most general use at the present time, is slate. Slate is an argillaceous sedimentary rock which, after being deposited as clay at a very early geological epoch, has been subjected to enormous mechanical pressure, the result of which has been that the beds have been squeezed together and the material rendered very dense and compact, while the original lines of stratification have been almost obliterated, and the particles have been rearranged in fresh planes perpendicular to the direction in which the pressure was exerted; along these planes the rock splits with great ease. The strength of the material has thus no connection with its natural bed, even when the latter can be discovered. This splitting or fissile property makes slate eminently useful as a building material, as, notwithstanding the fact that it is one of the hardest and densest of rocks, it can be obtained in such thin sheets that the weight of a superficial foot is very small indeed, and consequently, when used for covering roofs, a heavy supporting frame work is not required. Slate absorbs a scarcely perceptible quantity of water, and as it is very hard and close grained and smooth on surface, it can be laid safely at as low a pitch as 22½ degrees. In consequence of this the general introduction of slate as a roofing material has had a prejudicial effect upon the architectural character of buildings. The bold, high pitched, lichen covered roofs of the middle ages—which with their warm tints form so picturesque a feature of many an old fashioned English country town—have given place to the flat, dull, slated roofs, which evidently are so oppressed by their own ugliness that they gladly retire from view behind a parapet, with the result that in most of our modern cities we are confronted with miles and miles of streets whose houses appear to consist of fronts alone, terminating skyward in one dull, monotonous straight line. . . .

Slates should always be laid with a certain lap, that is, each course should overhang the next but one below it to a certain extent, and this should not be less than two inches. Thus there will be a certain width of slate in each course exposed, and this is called the gauge, its width diminishing as the lap increases. The gauge for any kind of slating is found by deducting the lap from the length of the slate, and then halving the remainder: thus, if Countess slates are laid with a 3 inch lap, the gauge will be $\frac{20-3}{2}=8\frac{1}{2}$ inches. Each course of slates "breaks joint" with the one below it. The average weight of ordinary slating may be taken at 7 cwt. per square of 100 superficial feet. The valleys of slated roofs are generally laid with lead, turned up under the slates, and the hip rafters are either covered with lead—which is the best plan—or with thick saddle back slates finished at top with an ornamental roll. Some years ago a system was introduced called patent slating. This consisted in laying large thick slates so that they butted against one another in a vertical line, the joints coming exactly over a rafter to which the slates were firmly screwed. The successive courses overlapped one another a few inches, and when the roof was covered, thin fillets of slate about three inches wide were bedded in putty over the vertical joints, tightly screwed down to the rafters, and pointed carefully all round. Slating could be laid in this manner to a very low pitch, and yet remain watertight for a considerable time, but it was found that a slight settlement of the roof was sufficient to injure it, and as the putty also soon perished, the system was abandoned, and it is now never adopted. It gave, however, a distinctly ornamental appearance to a roof.

The prevalence of the use of tiles for the best class of houses at the present time affords a curious example of the change that has occurred in architectural fashion in the last fifty years, for in Nicholson's "Architectural Dictionary," published in 1819, it is stated that "in consequence of the weight and fiery appearance of tiles, slates have almost universally superseded them, and tiles are used only for cottages or small buildings." The "fiery color" spoken of is undoubtedly bad, and if all the tiles were of the brilliant hue that is occasionally met with in country districts, it is probable that their use as a roofing material would have remained restricted. But lately manufacturers have succeeded in producing a warm reddish brown tint closely approximating to that of old weather tiles, than which nothing can be more pleasing. Tiles are made from clay in much the same manner as bricks, but as they are thinner they require a tougher clay and considerably more care in their manufacture. The clay is dug and weathered, and then ground in a pug-mill, so that it acquires great consistency. It is then formed into the required shape by being pressed into an oak mould, plated with iron. The clay is kept from sticking to the mould by dusting the latter with sand or fine coal dust. The tiles are then dried in the open air, and afterward baked in a kiln constructed on much the same principle as a brick kiln, but inclosed in a conical building called a dome. The period of burning depends upon the quality of the clay and the color to which the tiles are to be burnt. This general description applies to near all roofing tiles, but of course the moulding processes vary according to the kind of tile that is to be made. Till quite recently pantiles and plain tiles were the only kinds made, the former having a double curved surface, on the one side convex and the other concave, which shape is given to the plastic clay by hand. A small hollow in the mould gives the projecting nib by which pantiles are hung on the laths of a roof. The ordinary size of pantiles is 14⅛ by 10½ inches, and they are generally laid to a gauge of 10 or 11 inches. These tiles are only used for an inferior class of building, as it is difficult to keep a roof covered with them watertight for any length of time, as they can never be made to fit closely over each other at their lower edges, and consequently the rain has a tendency to drift up underneath them. They partially overlap laterally, but not sufficiently to make a watertight joint, and they are consequently frequently pointed with mortar, which forms a thick and ugly joint and soon perishes. The weight per square is about 10 cwt. The Bridgewater tiles are very similar to pantiles, but wider and formed with a double roll.

Plain tiles are oblong in shape with a very slightly curved surface, and they are either moulded with nibs for hanging on the laths, or are formed with two holes for nails or pegs. Their size is 10½ by 6½ inches. Many very excellent specimens of plain tiles have been shown at the various building exhibitions which have been held lately, but it would be difficult to find any superior to the best Broseley tiles, which are well burnt, even in texture, and of a very pleasant tint. Plain tiles, of the size mentioned above, should be laid to a 4½ inch gauge, and they are either hung to the laths by their nibs or by pegs driven through the holes in their surface. Some builders are fond of bedding the heading joints in mortar, but it is very doubtful if this is a good plan. Of course it makes the roof somewhat tighter at first, but my own experience is that tile roofs almost always fail in consequence of the laths becoming decayed and allowing the tiles to slip, and the presence of the mortar accelerates this decay. It is, moreover, certain that if mortar be used the tiler will be disposed to depend upon it for keeping the tiles in position, and will not devote so much care to the proper hanging and pegging of each tile, and as all roofs are subject to slight movement due to changes of temperature and varying wind pressures—have in fact a certain amount of "spring"—this will instantly act upon the mortar joint, and will tend to disturb it, and in a very short time the mortar begins to fall away and helps to block up the roof gutters. In some country districts it is the practice to lay the tiles on a bed of hay laid over the laths, and this plan appears to answer very well if proper care be taken, and it adds to the warmth of a building in winter. It is not desirable to give tiled roofs a less pitch than 45°, and 50° is preferable.

With ordinary plain tiles, those in any one course do not overlap laterally; consequently each course must overlap to a certain extent the next but one below it, or the rain would enter between the joints. Of late years many attempts have been made to obviate this necessity, which is the cause of the great weight of this kind of roofing, which is nearly a ton per 100 square feet. If tiles can be moulded so that they will fit into one another and form a watertight joint laterally, the successive courses need only overlap sufficiently to prevent the rain driving upward, and this can be prevented by forming a groove at the upper edge of one tile into which a corresponding projection on the lower edge of the next tile would fit. This method has been adopted with considerable success in Phillips' patent lock-jaw roofing tiles which interlock with one another on all four sides, and form such closely fitting joints that nothing can penetrate them; and the patentee claims that by exerting great pressure on the clay during the process of manufacture he is able to insure uniformity and perfect fit, without which the tiles would of course be practically useless. These tiles are of two different kinds, the "Single Grip" and the "Double Grip." The latter are suitable for the most exposed situations, and will stand the roughest usage. Half tiles are made for hanging next to a gable in alternate courses, in order to secure a perfect bond, in the same way that closers are used in brickwork. No mortar is required with them, nor any special skill in laying them. The difference between these tiles and the ordinary kind in the weight per square, 5½ cwt., and the number required, 150, is very striking, the weight being less than one-third that of the ordinary tiles. Taylor's patent tiles are moulded with a different kind of lateral overlapping arrangement. All these patent tiles give a decidedly ornamental appearance to roofs, as they break up the plain surface into a series of elevations and depressions.

It is curious to notice how closely some of the new patent systems of tiling resemble those in use among the Romans and in the early part of the middle ages. Tiles were used at a very early period for roof coverings, and were first formed with rims on each side, and under the rims were notches forming a lap laterally; and hollow tiles, similar to common hip and ridge tiles, were laid over the vertical joints, themselves overlapping each other. An improvement was effected by making the tile strapezoidal in shape, instead of rectangular, and thus the narrow end of one tile was pushed down till it closely fitted between the rims of the one below it; the notches under the rims were then discontinued, but the vertical joints were covered as before.

In the thirteenth and fourteenth centuries, in the old French province of Champagne, tiling was carried to very great perfection, and it is probable that no better tiles have ever been made than those which can be still seen in many buildings in Troyes and its neighborhood. The tiles are very like the modern Broseleys, but were made with one nib for hanging on the laths and one hole for nailing; and to show the extreme care which was taken with them, the position of the nib and the hole was reversed in each alternate course of tiles. This was done in order that, as the alternate courses were laid "breaking joint," the nail hole should always come over the center line of each rafter and the nib always midway between the rafters. The rafters were of course fixed in the proper position for the tiles, which were laid to a gauge of about 4½ inches; and as the length was 12¾ inches, there was always a lap of nearly 4 inches. In some of the tiles of this period the exposed portion of each tile was glazed, and thus rendered non-porous. This would be an excellent plan to adopt with modern tiles, but it would render them too expensive for general use. There is, however, another peculiarity in the best of these old French tiles which might easily be adopted by modern manufacturers, and which would be a great improvement, and that is the chamfering of the lower edge of the tile. The mould could easily be made of the shape requisite to form this chamfer, which would greatly diminish the risk of the tiles being ripped up by the action of a strong wind. The tiles of this period are frequently found in as good condition now as when first burnt.

The great objection to all tiles is their porosity, which causes them to absorb a considerable quantity of water, and this tends to rot the woodwork underneath. This wooden substructure consists in the case of both slates and tiles either of fillets of wood nailed on the rafters at intervals corresponding to the gauge required, or of close boarding similarly nailed to the rafters. For slates these fillets are generally 2½ inches or 3 inches wide and 1 inch thick, called slating battens, and the slates are nailed to them by nails—two to each slate—passing through small holes pierced in the slate itself. For tiles, which are much heavier, stouter fillets are required, and the tiles are hung on to these by pegs passing through the holes in the tiles, or by the projecting nibs, which have been already described. Close boarding is far preferable for either kind of covering, as it keeps the roof tighter and warmer, and in case it should be necessary for workmen to pass over the roof for any purpose after its completion there is much less danger of the slates or tiles being broken than with battens. The risk of damage from high winds is also much less, but this point will be referred to more in detail farther on.

In country districts the roofs of cottages and outbuildings are frequently covered with thatch. This consists of layers of straw—wheaten straw is the best, lasting twice as long as oaten—about 15 inches in thickness, tied down to laths with withes of straw or with string. Thatch is an excellent nonconductor of heat, and consequently buildings thus roofed are both cooler in summer and warmer in winter than others, and no better roof covering for a dairy can be found. Thatch is, however, highly combustible, and as it harbors vermin and is soon damaged, it is not really an economical material, though the first cost is of course small. A load of straw will do a square and a half of roofing, that is, 150 superficial feet.

Felt is often used for covering the roofs of outbuildings. It should be nailed down to close boarding, the edges of the sheets overlapping, and if a double layer be applied, with a coating of tar on each, and the top layer to be sprinkled over with sand, it forms a good and cheap covering for a time. It requires, however, a fresh application of tar and sand every two or three years. In Germany a material closely resembling felt, called "*Dachpappe*," is frequently employed for covering roofs of manufacturing premises. This is a species of pasteboard or *carton-pierre*, two layers of which are nailed to close boarding and tarred and sanded. Roofs covered with this material are laid to a very flat pitch, not more than sufficient to throw the water off in one direction, and instead of fixing a gutter at the eaves, small fillets of wood are nailed to the boarding, sloping in two directions upward and meeting at the bottom, where an outlet for the water is formed. These fillets are completely covered with the *Dachpappe*. These roofs are extremely light, and if the material is carefully laid they remain watertight for a considerable period.

The structural arrangement of a building frequently renders it impossible to form a sloping roof over all parts of it, and hence flats are necessary. When this is the case, metal coverings are the best that can be adopted. Formerly it was not uncommon in buildings where cost was not a consideration to use sheet copper for covering flats or slight slopes, and a large portion of the roof of the British Museum galleries is laid with this material. Copper forms a very light covering, as it may be safely used in sheets not more than 0·3 inch thick, which would weigh about 20 oz. per foot super. Copper slowly oxidizes when exposed to the air, but the oxide does not eat into the substance of the metal, as is the case with iron; it seems rather to form a protective coat. The cost of copper renders its use very limited, and zinc has to a large extent taken its place.

Zinc is also a very light covering, in fact its specific gravity is slightly less than that of copper, but it has not a good reputation, owing to the fact that on its first introduction it was used in very thin sheets, and sufficient care was not taken in laying it. Its expansion is greater than that of any other metal, and therefore it should always be laid with ample play, or it will soon buckle and crack. The Vieille Montagne Company have greatly improved the methods of laying zinc, and they have also introduced thicker sheets than could previously be obtained; and if zinc is used at all it should never be less than No. 16 gauge, which weighs about 24 oz. to the foot super, and is as nearly as possible $\frac{1}{39}$ of an inch thick. Zinc resembles copper in the fact that it oxidizes on the surface only, but in smoky districts it will not last at all, as sulphuric acid completely destroys it.

The surface oxidation only of zinc when exposed to ordinary atmospheric influences suggested the attempt to prevent the rusting of iron by giving it a thin coating of zinc. This led to the production of galvanized iron for roofing purposes. The galvanizing process consists in first precipitating tin upon sheets of iron by means of weak galvanic action, and then placing the plates in a bath of liquid zinc. Iron thus treated will last, under favorable circumstances, for a long time, but when used for roofing it is almost impossible to avoid nailing the sheets in some places, and where the nail holes occur, moisture invariably makes its way to the iron itself, which rusts internally, and the thin zinc coating then comes off in flakes. What was previously stated as to the action of sulphuric acid upon zinc will show the utter uselessness of galvanized iron in smoky districts.

The most durable metal covering for roofs is milled lead. This is lead which after being cast is passed through a mill between rollers adjusted so as to give the requisite thickness to the sheets which are rolled out. This thickness varies from 0·075 inch to 0·236 inch, the weight of these qualities being 4 pounds and 14 pounds respectively per superficial foot. The qualities chiefly used for roofing are the 5, 6, and 7 pound lead, the latter being the lightest that should be used for flats or gutters. In laying lead on flats they should be close boarded, and care must be taken to allow for the due expansion and contraction of the metal; consequently the

* A paper by John Slater, B.A., Fellow of the Royal Institute of British Architects. Published in the *Sanitary Record.*

joints of two adjacent sheets must not be soldered together. In order to prevent the water from penetrating at the joints, fillets of wood 2½" × 2", rounded at the top, called rolls, are nailed to the boards, and one sheet of lead is dressed close up to and half way over the roll, while the next sheet is brought up to the opposite side of the roll, and lapped completely over the roll and the turned up portion of the first sheet. If the lead is closely hammered down with wooden mallets no nails are required, and they are better omitted. When it is necessary to nail the lead around skylights or in other positions, copper nails should always be used.

There is one very interesting question connected with roof coverings which can only be briefly alluded to here; and that is the actual effect upon them of wind pressure. A gale of wind never passes over a city without blowing down into the streets a number of tiles and slates, to the imminent danger of passers by. The cause of the slates being blown off is not quite so simple as might at first be imagined. Where loose ridge tiles or broken slates occur these are blown off as a matter of course, but it frequently happens that roofs which were perfectly sound are seriously damaged. As the direction in which the force of the wind acts is horizontal, there would seem to be no tendency to rip up or break off materials lying so closely upon one another as slates. The true explanation is probably this: Any exceptionally strong gust of wind is succeeded by a momentary vacuum, and as under ordinary circumstances the atmospheric pressure inside and outside a roof is equal, it follows that during the brief continuance of the vacuum outside the pressure inside is considerably in excess, and the weakest points of the roof covering will have a tendency to be pushed outward. Now in roofs covered with battens, to which the top only of the slates are nailed, the lower portions of the slates would be much less able to resist any such outward pressure, and would be forced upward, and if at such a moment another gust of wind were to occur it would find its way under the slate and break it. If the rafters were covered with close boarding instead of battens, this would offer a far more even resistance, and for this reason close boarded roofs are much less liable to damage from wind. The whole question of the action of wind upon sloping roofs has not received the attention from professional men that its importance demands.

[NATURE.]

SOUND-MILLS.

AFTER the notable researches of Crookes on radiation, which culminated in the discovery of the radiometer, or light-mill, it was a natural transition of thought which suggested to several minds almost simultaneously the possibility of devising an apparatus which should rotate under the influence of sound waves as does the radiometer under the influence of the rays of light and heat. Such instruments were indeed devised independently about six years ago by Lord Rayleigh, by Prof. Alfred M. Mayer of Hoboken, by Mr. Edison, the well-known inventor, by Prof. Mach of Prague, by Dr. A. Haberditzel of Vienna, and by Prof. V. Dvorak of the University of Agram (in Croatia). These researches, though of great scientific interest, have been somewhat overlooked in the rush of scientific inventions during the intervening years. During the course of the past year, however, Dvorak has given to the world, in the pages of the *Zeitschrift der Instrumentenkunde* (vol. iii., Heft 4), a detailed account of his experiments, together with figures of various piece of apparatus hitherto undescribed. We propose to give a *resume* of the principal points of Dvorak's researches.

Four kinds of sound-mills are described by Dvorak, two of them depending on the repulsion of resonant boxes or cases, and two others on different principles.

The first of these instruments is depicted in Fig. 1, and consists of a light wooden cross, balanced on a needle point, carrying four light resonators made of glass. These resonators are hollow balls of 4·4 cm. diameter, with an opening of 0·4 cm. at one side. They respond to the note g' (=392 vibrations). When the note g' is forcibly sounded by an appropriate tuning fork, the air in each of the resonators vibrates in response, and the apparatus begins to rotate. As a resonator will respond when placed in any position with respect to the source of sound, it is clear that one single resonator properly balanced should rotate; and this is found to be the case, though, naturally, the action is more certain with four resonators than with one.

Before proceeding to the other forms of sound-mill devised by Dvorak, it may be well to explain briefly the cause of the phenomenon, and to describe Dvorak's particular method of exciting the appropriate sound. Dvorak has pointed out, as indeed has been done elsewhere both by Lord Rayleigh and by Prof. A. M. Mayer, that, when sounds of great intensity are produced, the calculations which are usually only carried to the first order of approximation cease to be adequate, because now the amplitude of motion of the particles in the sound-wave is not infinitely small as compared with the lengths of the sound-waves themselves. Mathematical analysis shows that under these circumstances the mean of the pressures in the condensed part and in the rarefied part of the sound-wave is no longer equal to the undisturbed atmospheric pressure, but is always greater. Consequently at all nodal points in the vibrations of the air in tubes or resonant boxes, the pressure of the air is greater than elsewhere; and therefore any resonator closed at one side and open at the other is urged along bodily by the slight internal excess of pressure on the closed end. The apparatus, Fig. 1, therefore rotates by reaction, in the same way as Hero's primitive steam-engine rotated, though the reaction is due to a different cause.

To produce vibrations of sufficient intensity Dr. Dvorak employs heavy tuning-forks mounted on resonant cases, and excited electrically. For this purpose he places between the prongs of the fork an electromagnet constructed on the following plan. Two plates of iron separated by a sheet of paper are used as a core. They are cut of such a breadth as to lie between the prongs without touching them. This core is overwound with insulated copper wire, as shown at E, Fig. 2, and the electromagnet is then mounted by a bent piece of wood, *a b c*, upon the sounding-box, K, of the fork. The wires are connected in a circuit with a battery, and with the electromagnet of a self-exciting tuning fork of the same note. Dr. Dvorak is extremely particular about the arrangements of the resonant boxes of his tuning-forks. They must not touch the table, the arm, *a b c*, being clipped at about the point, *b*, in a firm support. Moreover, the resonant boxes themselves require to be specially tuned, for all are not equally good. Dr. Dvorak points out that, besides the tone of the fork, and the tone of the air column in the cavity of the box, there is also a tone proper to the wood of the box itself which in most of the forks used in acoustic researches is too base, the wooden walls being too thin. To hear this tone the prongs of the fork should be damped by sticking a cork between them, and the cavity should be filled with cotton wool, while the wooden box is gently struck with the knuckle or with a cork hammer. It is important that the wood-tone should be tuned up to coincidence with the tone of the fork and with that of the air in the cavity. Dr. Dvorak himself used the box depicted further on in Fig. 6, in which drawing F is the socket into which the stem of the fork was screwed. The wood was tuned by planing it away at the top and bottom, while the air cavity was tuned by enlarging the circular opening in front. In the later researches the box stood on four feet made of India rubber tubing. The note of the fork so mounted was very strong. At 40 cm. distance it would set the sound-mill in motion.

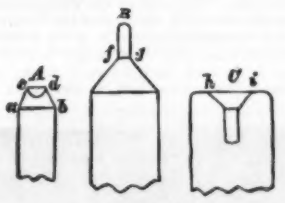


FIG. 5.

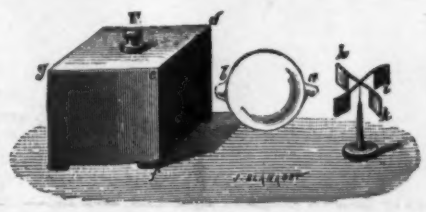


FIG. 6.

Dvorak's second apparatus, a "rotating resonator," consists of a short cylindrical box, constructed of stiff glazed paper, having four projections, shown in plan and elevation in Fig. 3, each of which bears at its side a short open tube of paper. It is, in fact, a resonator with four openings, arranged so that it can be hung upon a silk fiber. A fine needle projects also below to steady the motion during its rotation, which occurs whenever the apparatus is brought near to the sounding-fork. For the note g' the dimensions were: diameter, 7 cm.; height, 3·6 cm.; diameter of openings, 0·6 cm.

The third apparatus is the "sound-radiometer" described by Dvorak before the Imperial Viennese Academy in 1881. Its cause of action is less readily explained, though its construction is even more simple. Its form is shown in Fig. 4, D; there being, as before, a light cross of wood, pivoted by a glass cap upon a vertical needle. To the four arms of the cross are cemented four pieces of fine white card, about 0·08 cm. thick, perforated with holes which are depressed conically at one side, and raised at the other. These holes may be made by punching the card upon a lead block with a steel perforating-punch of the form shown in Fig. 5, A, the dimensions of which are: $a\ b$=0·38 cm.; $c\ d$=0·2 cm. The holes should be from 0·6 to 0·65 cm. apart from one another. When a card so perforated is held in front of the opening of the resonant box of the tuning-fork, it is repelled if the smaller ends of the conical holes are toward the box; or is attracted if the wider openings are toward the box. A better but less simple way of perforating the cards is by the use of the conical steel punch shown in Fig. 5, B; and the matrix, Fig. 5, C. The angle of the cone is 55°, and the narrow projecting nose of steel is 0·2 cm. The card should be damped, laid on the matrix, C, and the whole pierced by two or three blows upon the die. Dr. Dvorak prefers this plan; it throws up a high burr or edge behind the conical hole, and such perforations are more effective. The cards may be varnished, and are then mounted upon the cross. The rotations are more rapid if the cards are set on obliquely in the fashion shown in Fig. 4, E, the burred sides being outward. Cards with twenty-five perforations so mounted rotate briskly when the "mill" is set in front of the resonant box.

The fourth apparatus of Dvorak is called by him an "acoustic anemometer." It is shown in Fig. 6. This is merely a little "mill" of simple construction, the vanes being small pieces of stiff paper or card slightly curved. The sounding box previously described is placed a little way from it, and between them is held an ordinary Helmholtz's resonator, with its wide mouth, *b*, turned toward the box, and its narrow opening, *a*, toward the mill. From what has been previously said it will be understood that the internal increase of pressure in the resonator at *a* has the effect of driving a jet of air gently against the sails of the mill, which consequently rotates. Dr. Dvorak also suggests that this two-aperture resonator may be replaced by one having but one aperture, as shown at R, with its open side, *l*, turned toward the mill. This resonator is formed of a glass ball cut away at one side and cemented to a glass plate having a small hole at the center. It may be remarked that when the air ejected from the mouth of this resonator is examined by the method of mixing smoke with it, and then viewing it through slits cut in a rotating disk, the currents are seen to consist of a series of vortex-rings.

A second kind of "acoustic anemometer" may be made by taking a card pierced with 100 conical holes, as previously described, and placing this between the resonant box and the "mill." The latter rotates in the wind which passes through the conical holes.

Space does not admit of a comparison being drawn between these instruments and those of Mayer, Mach, and others, which are very closely akin in their design and mode of action, interesting though such a comparison might be. Nor can we here compare the action of these instruments with the "phonomotor" with which Mr. Edison literally accomplished the feat of talking a hole through a deal board. But this remarkable machine was a purely mechanical toy, which converted the vibrations of the voice, by means of a very finely cut ratchet-wheel, into a motion of rotation round an axis.

SILVANUS P. THOMPSON.

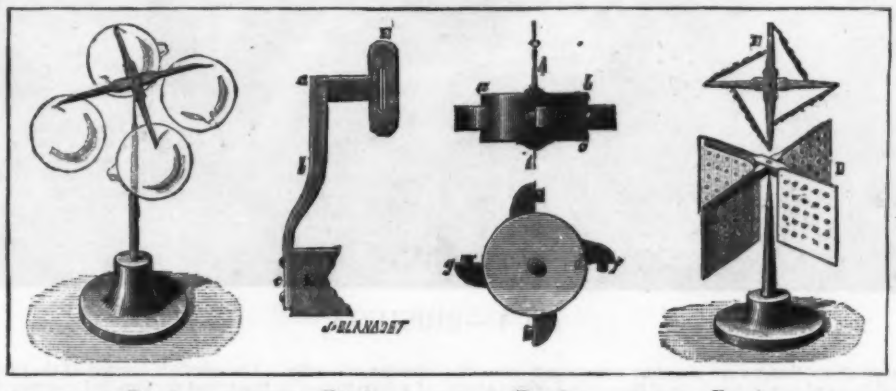
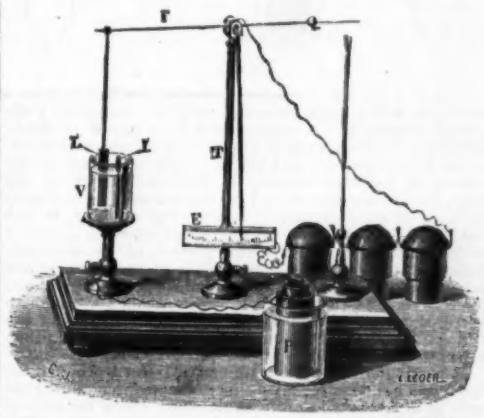


FIG. 1. FIG. 2. FIG. 3. FIG. 4.

MARCILLAC'S APPARATUS FOR REGISTERING THE WORK OF PILES.

MR. MARCILLAC'S apparatus for registering the work of piles, as exhibited at Vienna, consists of a sulphate of copper voltameter, V, formed of a fixed strip, L', and another one, L, suspended from the beam of a balance. The current from the pile to be tested (P) traverses the voltameter after passing through the rod, T, the beam, F, and the standard of the apparatus. The needle carried by the beam moves under the influence of the increase in weight of the strip L, and its extremity passes over the arcs plate, E. These arcs, according to the inventor, are proportionate to the work effected. The plate, E, being covered with paper prepared with cyanide of potassium, and the entire system being traversed by a current from a second pile, the needle traces upon the paper the arcs that it is passing over. Its position, then, must be noted from time to time. It must be remarked that there is no mechanical arrangement in this apparatus for automatically establishing an equilibrium again. There is, however, a certain compensation therefor, since the strip, L, on descending further and further, experiences greater and greater thrusts on the part of the liquid. We do not think, however, that the apparatus is capable of being very accurate.—*La Lumière Electrique.*



MARCILLAC'S APPARATUS FOR REGISTERING THE WORK OF PILES.

MICHAELIS'S PHOTO-THERMOMETER.

THE laying of marine cables has given great practical interest to the determination of the temperature and currents that are met with at great depths. In No. 4 of the *Centralblatt für Elektrotechnik* of this year we find a *resume* of what has thus far been done in this line, and a detailed description of a new apparatus due to Dr. Hugo Michaelis, and designed for registering the temperature corresponding to a given depth. As regards the ascertaining of temperatures, the first instrument that offered itself was the maximum thermometer. But this instrument, unfortunately, which is a costly one, does not resist strong pressures well, for as soon as a depth of 7,000 meters is reached we can feel pretty certain that the apparatus has broken, and at less depths it becomes so compressed that the indications it furnishes are absolutely erroneous.

At Melbourne, Mr. V. Lendenfeld proposed a registering thermometer based upon the same principle as the alarm thermometer, the movement of a column of mercury being utilized to close a series of circuits, so that its movements could be followed at a distance. Mr. C. W. Siemens devised a compensating electric thermometer for measuring submarine temperatures by means of the variations of resistances in the circuit. Mr. Henmayer was the first to think of reg-

istering the height of a column of mercury by photography. For this purpose he employed a Geissler tube filled with nitrogen. The thermometer was placed between this and a cylinder moved by clockwork and carrying paper prepared with chloride of silver. An induction coil and a battery completed the apparatus.

Dr. Michaelis's photometer is analogous in principle to that of Henmayer, but possesses numerous advantages over the latter, especially that of operating intermittingly, and consequently of not heating appreciably. The apparatus is shown in longitudinal section and plan in Figs. 1 and 2. It consists of a cylindrical cast iron case, A, provided with a lug to which the sounding cable is attached. In the interior of the case there is an incandescent lamp, B, and a vertical cylinder, D, surrounded with photographic paper. To the axis of this cylinder is keyed a cogwheel, E, whose

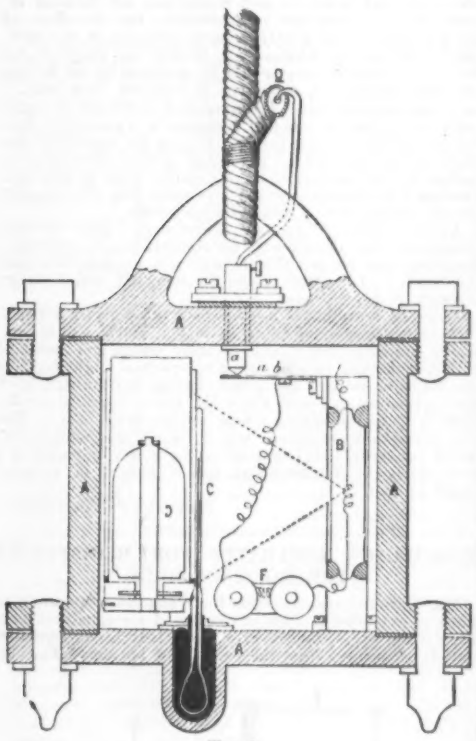


FIG. 1.

teeth gear with a click connected with the armature of the electro-magnet, F. A thermometer, C, is placed vertically between the cylinder and the lamp, and its reservoir is surrounded with mercury and held in a short tube fixed in the bottom of the case. Owing to the conductivity of the sides, the thermometer soon feels the influence of the temperature of the surrounding water. The cylinder, D, and the lamp, B, are inclosed in fixed tubes containing apertures so arranged as to withdraw that portion of the sensitized paper that is outside of the projection of the thermometer tube from the influence of the luminous rays. The cover of the case carries two terminals to which are attached the line wires, and each of which communicates with one of the springs, *b* and *a*. These wires are insulated on board the vessel through the cable, Q.

In making an observation we first note the depth that the apparatus has reached, this being got at by ascertaining the number of revolutions of the drum upon which the cable is wound. Then a current is sent through the line. This passes through the terminal, through *b*, through the bobbins of the electro-magnet, F, the lamp, B, the spring, *a*, and

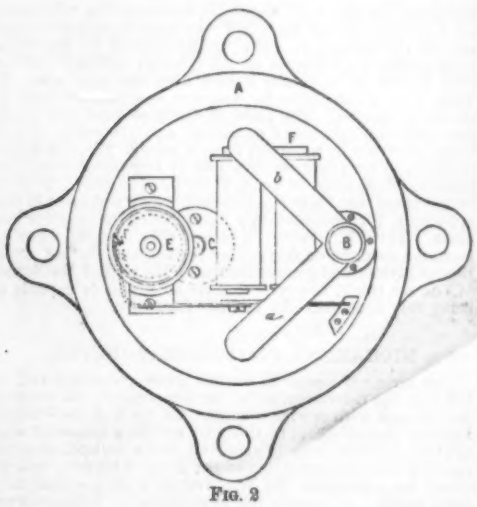


FIG. 2

finally through the other terminal. There is thus obtained a luminous impression. When the circuit is closed, the armature of F is attracted and the click advances by one tooth upon the wheel E, which latter is prevented by another click from revolving from right to left. As soon as the current ceases, a spring brings the armature back to a state of rest, and, in this motion, causes the wheel, and consequently the sheet of paper, to move, so that everything is ready for a second experiment. After a certain number of observations the apparatus is hauled up on board, and the sheet of paper is unwound and taken to a dark room and submitted to the ordinary operations for obtaining positive proofs.

It results from the experiments made by Dr. Michaelis and Prof. Vogel in the photographic rooms of the Polytechnic Institution of Berlin that it is only necessary to expose the sensitized paper (prepared with bromide of silver) for a quarter of a second to the light of a Swan lamp in order to obtain a very sharp photograph of a thermometer tube. From this standpoint it will be seen that the apparatus is very satisfactory, and that the heating that might, at first sight, be feared is absolutely out of the question.—*La Lumière Electrique.*

SUBMARINE EXPLORATIONS.*

AT great ocean depths we find in company with those singular Holothurians which we recently mentioned, and which are called *Psychropotes* and *Oneirophantæ*, others that possess forms that are sufficiently strange to fix our attention for a few moments. We refer to the *Peniagones*. While the Psychropotes are of a dark violet, and the Oneirophantæ of a dull white, the Peniagones are of a pure rose-color. They are quite small in size, and their shape is very remarkable, for there rises from their back a sort of fleshy plate that is spread out like a fan and toothed at the edge. The genera

FIG. 1.—BRISINGA.

of Holothurians that we are directing attention to give the abyssal fauna of certain portions of the ocean a very peculiar physiognomy. The species that they include seem sometimes to represent the entire life of the depths, and we were always struck with the extreme abundance of the individuals brought up in the trawl; thus, on the 27th of August, we captured at a single haul of the net, and from a depth of 5,005 meters, more than fifty Peniagones.

The Holothurians fished up by the Talisman are not alone remarkable for their singular forms (their bright hues proving that an error was committed when it was supposed that there could be no colors whither light did not penetrate), but are also very interesting to study by reason of the transformation that their body undergoes in shape.

Thus, says Prof. Perrier, who made a special study of these animals on the Talisman, "a Holothurian has essentially the shape of a five-sided melon having an aperture at each extremity. Now in Holothurians of great depths this form almost entirely disappears. There are some that are bent like a U, and others (*Ankyroderma*) that are shaped like an ovoid bag, without those ambulacra that divide the surface of some species into five ellipses. The majority (*Psychropotes, Oneirophanta, Peniagona*, etc.), instead of the characteristic symmetry of the radiates, exhibit a bilateral form as clearly defined as that of the worms and vertebrates, and crawl along the mud by means of a ventral sole similar to that of slugs. This is a singular example of the manner in which two organic types that seem to be separated by an uncrossable abyss may be superposed upon the same animal."

The Echini, commonly known as sea-hedgehogs, are represented at great depths by very varied and special forms at certain points. Certain species of these are remarkable for the size and elegance of the rods that cover their shell, and we may cite more especially, as regards such characters, *Dorocidaris papillosa*, that we found at depths of 400 and 1,100 meters, and specimens of *Solenia* that came from depths of 640 and 2,638 meters. But the most interesting forms, and those most peculiar to great depths, are the *Pourtalesiæ*, some rare examples of which were taken by us at depths of nearly 2,500 meters. The shell of these Echini is absolutely different from that of all other species, being greatly elongated, nearly cylindrical, and truncated at the anterior extremity. The mouth is located at the extremity of a deep furrow in front, and the terminal aperture of the digestive tube is found upon the dorsal surface. The spines are short, and in certain species enlarged at their apex in the shape of a spatula. There are other very curious genera that are likewise peculiar to great depths, and, among them, may be mentioned the *Calverias*. Remains of these echinoderms have been known for a long time amid the deposits of the Cretaceous epoch, but it was not till 1869, during the cruise of the English vessel Porcupine, that the survival of this form at the bottom of our seas was revealed to us. The first of these living *Calverias* was met with in N. lat. 59° 38′ and West long. 7° 46′, at a depth of 814 meters, where the temperature was 7·05° C. "In measure as the trawl came up," says Thompson, "we perceived in the bottom a large scarlet Echinus that we thought must be a striking form, of unusual size, of *Echinus Flemmingii*. As the wind was quite furious, and as it was not easy to invert the trawl in order to empty its contents, we resolved to put up with what seemed to us an inevitable necessity—the extraction of the animal in a thousand pieces. We saw it, however, with astonishment, roll out of the net without the least harm; and our surprise only increased the more, and

* Continued from SUPPLEMENT No. 440, page 7026.

mingled, as far as I was concerned, with a certain emotion, upon seeing the animal stop, assume the form of a reddish spheroid, and begin to palpitate. Its shell, which was as flexible as the softest leather, was lifted by the most singular undulations, and I was obliged to appeal to all my coolness before taking this little monster in my hands." This extreme flexibility of the sides of the singular Echinus that had just been discovered was due to a very peculiar arrangement of the different pieces that made up the shell. The ambulacral and interambulacral plates, which, in other living Echini, meet by their edges, and join to form a continuous shell, here remained independent of each other and mutually overlapped. As for the palpitating motion that seems to have caused so profound an impression upon the learned English naturalist, it appears to us to be well demonstrated, from numerous observations, that its mode of origin and its nature were not well understood. We have often had occasion to examine absolutely intact specimens of *Calveria*, and never have we seen a spontaneous motion occur therein. They did, as Thompson says, put themselves out of shape, and they also palpitated at certain instants, after a fashion, but all such phenomena were simply due to the rolling and pitching motions of the vessel, or else to the transmission of vibrations proceeding from the working of the different steam engines on board. *Calveria* and the closely allied Echini, *Phormosomas*, are the most abundant kinds at great depths. We have taken them at depths of from 608 to 4,250 meters, and those that we captured were so many new species.

Those marine animals of elegant and brilliantly-colored forms that are called by the general name of sea-stars, constitute one of the richest groups, as regards genera and new species, that exists in the Talisman collection.

Especially worthy of attention are the *Brisingas* (Fig. 1), whose long and flexible arms sometimes number as many as twenty. These brilliant Asteroids, of an orange-red color, generally rid themselves of their appendages by a violent effort when they perceive that they are taken and are being carried along in the ascent of the trawl, and it was only exceptionally that it was possible for us to see any that were whole. Mr. C. Abejornsen, who was the first to have the good fortune to discover them off the coast of Norway, a little above Bergen, at a depth of 200 fathoms, could not escape a feeling of admiration in the presence of the phosphorescent light that was emitted from their body and arms. "Complete and intact, as I have seen it once or twice under water in the trawl, this animal is singularly brilliant, and is a genuine *gloria maris*," says he, and he therefore gave it the name of *Brisinga*, which is borrowed from that of a jewel of the goddess Freya. *Brisinga coronata*, which has hitherto been found only in the northern ocean, we captured in the tropics. The Porcupine expedition took it at a depth of 914 meters, and we found it at a depth of between 736 and 1,435. At a depth of between 882 and 3,455 meters we fished up *Brisinga robusta;* at 2,384. *B. spinosa;* at 1,435, *B. semicoronata;* and at 2,230, *B. Edwardsi*. All these forms were new, and the last was so abundant where we captured it that thousands of individuals must have covered the ocean bottom. After the *Brisingas*, the most singular sea-stars that we met with were *Zoroasters* (at depths of 3,200 meters); *Ophiomuniums*, abundant at from 750 to 3,125 meters; *Chetasters*, one species of which (*C. longipes*) was brought up from 3,200 meters; and many species of *Archaster* peculiar to different zones, one of which, *A. rigidus* (a large form), appeared to us to be characteristic of the greatest depths that we explored (5,005 meters). In a former article, in speaking of crustaceans, we called attention to the very singular increase in the ventral plates of *Glyphus marsupialis*, that so develop as to form a pocket for the reception of the eggs. In certain sea-stars called *Hymenaster* there likewise exist organs for the protection of the eggs. The body of these echinoderms, seen in dorsal view, appears at first sight to be entirely membranous, but a profounder study shows that the membrane that covers the body is not the skin. It is entirely different from the latter, and constitutes a sort of tent that shelters the back. The eggs are arranged in the interior of this and are hatched therein, and the young live and grow there until they are capable of shifting for themselves. The color of these animals is of a pure-rose color variegated with violet, and, when the membranes are swollen with water, the star assumes the rounded form of a tulip. A few species of *Hymenaster*, such as *H. rex* and *H. Bourgeti* (new forms), are met with a depth of 4,000 meters. Crinoids (Fig. 2), the last of the echinoderms that we have to speak of, are animals whose body is cup-shaped. From their sides start arms that are bifurcated or ramified, and provided with pinnules along the edges. From the dorsal surface there starts a jointed stem which is fixed by its lower extremity to surrounding objects. In the genera *Antedon* and *Actinometra* (represented in Fig. 2) the stem exists only in the young individual, the body becoming free at a certain period of its development, while in *Pentacrinus* (also shown in the engraving), in *Democrinus* and *Bathycrinus* it persists during the entire life of the animal of which it forms part. Crinoids have always been considered by naturalists as objects of the highest interest for study, not only because of their great rarity in the midst of the present sea fauna, but also because of their extreme abundance during very ancient geological epochs. In fact, these animals, which were already very common during the Silurian period, became multiplied at the time of the deposition of the Carboniferous calcareous strata, which consist of deposits that are almost entirely composed of their debris. They are found again in abundance in that horizon of Triassic deposits called muschelkalk; then, after this period of extraordinary prosperity, the order of crinoids, as Thompson says, appears to have had the underhand in the struggle for existence. The species, which are rarer and rarer in measure as we approach the present period, are represented by less and less numerous individuals, and, at one time, it was thought that the *Antedons* alone had been perpetuated to our day. The discoveries that have accompanied submarine explorations at great depths have had the result of causing such a belief to be abandoned. Certain forms of crinoids, like *Pentacrinus*, *Democrinus*, and *Bathycrinus*, are peculiar to great depths, and constitute very numerous and widely separated colonies in the midst of our oceans.

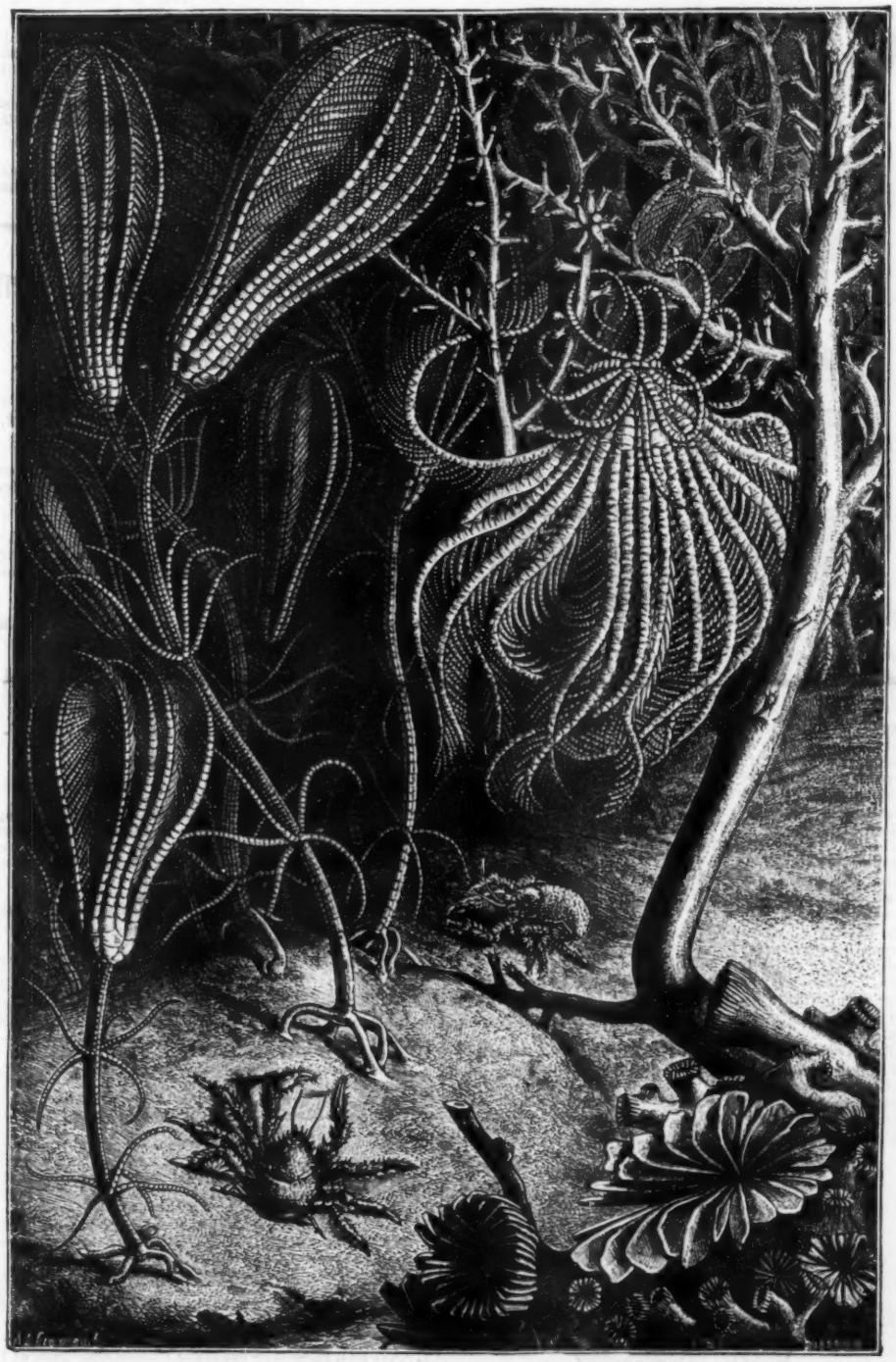


FIG. 2.—PENTACRINI, MOPSEES, AND POLYPS.

The first *Pentacrinus*, a genus well represented in the lias and oolitic strata, was brought from Martinique to Paris in 1755, and described by Guettard in the Memoirs of the Royal Academy of Sciences. At long intervals, a few rare examples have been seen that were derived from the Sea of the Antilles. On the 21st of July, 1870, Gwyn Jeffries, in dredging from the Porcupine at a depth of 2,000 meters, in N. lat. 39° 42' and E. long. 9° 43', and at a temperature of 4·3° C., captured twenty specimens of a new species—*Pentacrinus Wyville-Thompsoni*. The fine state of preservation of these specimens seemed to be capable of showing whether these animals lived free or fixed. Thompson, after an examination of one of the specimens, says that "the lower surface of the terminal articulation was rounded, and that this proved that the animal had long lived at liberty." Farther on, this learned naturalist adds:

"I do not doubt that this peculiarity is habitual in the species under consideration, and that the animal lives slightly fixed in the soft mud, but changes place at will, swimming by means of its pinnate arms, and occupying in this respect a place intermediate between the genus Antedon and the decidedly stationary crinoids."

On board the Talisman we twice let down our trawl to bottoms occupied by *P. Wyville-Thompsoni*—once off the coast of Morocco, and once nearly opposite Rochefort—and we found, after drawing up pieces of rock, that these animals lived, contrary to what might have been supposed, completely fixed through curved cirri that started from the terminal joint of the stem. These hook-like organs become soldered, after a manner, to the bottom upon which they rest (see engraving), and they must be broken in order to detach them. Consequently the *Pentacrini Wyville Thompsoni* that have been met with in a free state must have been torn by some accident from the bottom upon which they were living, since it appears to be difficult to admit that the same animals have different modes of existence at different points in the ocean.

In Fig. 2, we have endeavored to render the aspect of the bottom of the sea on which *Pantacrini* are living, as revealed to us by the dredging effected opposite Rochefort, in 1,500 meters of water. The *Pantacrini* covered the bottom in considerable numbers, and formed a sort of animated prairie in the midst of which stood mopseës of large size. The rocky soil was covered with very elegant polyps that resembled true flowers with open corolla; and, in the midst of this living world, chained to the earth, were crustaceans that were as yet unknown (*Paralomis microps*), and whose shell was provided with fine spines. *Actinometras*, free crinoids, detached from their stem after their complete growth, were floating amid the waters or fastening themselves now and then, through their cirri, to the branches of the mopseës. The *Pentacrini Wyville-Thompsoni* and *Actinometras* were of a beautiful grass green, the mopseës of an orange tint, the polyps of a dark violet, and the crustaceans of a pearly white. This exuberance of life and excess of color at 1,500 meters from the surface of the ocean certainly constitutes one of the most wonderful facts that was reserved for naturalists to discover.—*H. Filhol, in La Nature.*

ON ANIMAL CHLOROPHYL.

WHETHER chlorophyl is an exclusively vegetable product, or whether it is also elaborated by certain members of the animal world, is a question which has been not unfrequently discussed of late years without any decisive result. Recently, however, a series of researches on the chlorophyl of the lower animal forms has profoundly shaken the faith in a genuine animal chlorophyl. Morphological, physiological, and chemicophysical observations have shown, or seemed to show, that the chlorophyl-granules found in rhizopods, sponges, polypes, and ciliata are merely distinct vegetable individuals, algæ, which inhabit the animals in question in a semi-parasitical manner, just as do algæ and fungi in lichens.

It need scarcely be said that, if such is universally and exclusively the nature of the chlorophyl observed within the bodies of animals, it is the great and certain feature by which animals and plants are distinguished from each other. This generalization, cannot, however, as yet claim our acceptance, since Herr T. W. Engelmann ("Pflüger's Archiv für Physiologie") has published certain observations which, to say the least, must render the above mentioned assumption very questionable.

Some years ago Engelmann met with Vorticellæ whose tissues did not contain distinct granules of chlorophyl, but displayed a diffused homogeneous green color as if from imbibed chlorophyl. As at that time the occurrence of animal chlorophyl was not questioned, he paid no further attention to these animalcules. Now, since the closer investigation of this coloring-matter has become of capital importance, he returned to the subject. He met with the necessary specimens only after long search, and in small numbers. He found upon *Vaucheria*, both living and dead, along with numerous colorless specimens of *Vorticella campanula* and *V. nebulifera*, a few Vorticellæ of a diffused green color. In addition to their color, these were distinguishable by the closer and more delicate annulation of their bodies, and by a greater transparence of their endo-

PUBLIC LIBRARY

plasm. The green coloration was strictly limited to the ectoplasm. In recent specimens the color was quite homogeneous. It was deepest in the so-called cuticle, and was wanting on the surface of the peristomal disk. The entire endoplasm and the long nucleus seemed to contain not a trace of chlorophyl. In different specimens, however, both the intensity and the distribution of the color were found to vary.

The important question whether living chlorophyl—or at any rate a genuine, assimilating chlorophyl—was present was investigated by Engelmann by means of the so-called bacteria method. He added a small quantity of a liquid containing bacteria to a drop which contained a bright green *Vorticella* attached to a dead branch of *Vaucheria*. The latter was free from chlorophyl. The preparation was placed in the "dark box" of the microscope, and the *Vorticella*, by means of a suitable arrangement, was illuminated by a spectrum. After about a quarter of an hour a distinct accumulation of movable bacteria was seen round the *Vorticella*, while previously none or but few had been seen.

Without doubt these Vorticellæ possess the property, by means of the diffused green coloring-matter of their ectoplasm, of evolving oxygen under the stimulus of light. Thus we have here the first undoubted animals which assimilate by means of a chlorophyl forming part and parcel of their own living structure, and not by the mediation of vegetable guests.

The fact that the bacterial reaction, as regards its slight intensity, may be compared with that of infusoria, which harbor living chlorophyl granules to some extent, is explained by Engelmann by the consideration that the assimilating coloring matter was present only in very small quantity. Further, the Vorticellæ themselves consume much of the oxygen liberated, so that they can throw off but little externally. The Vorticellæ, indeed, as the author has proved by a series of observations, have a great need of oxygen—a fact which agrees well with the supposition that they can prepare a supply for themselves.

Herr Engelmann has instituted further experiments in order to decide whether the coloring-matter of these animalcules is identical with the chlorophyl of plants, or whether it is a peculiar and merely analogous chromophyl. To this end the assimilative energy in the various colors of the spectrum was tested by means of the "bacteria method." Its behavior was found similar to that of the green color of plants. The coloring-matter was next obtained in the form of globules, and examined with the spectroscope. There was found a well-marked absorption-band in the red, between B and C, and an absorption at the extremity beginning with F. These peculiarities testify for the identity of the color of the Vorticellæ with vegetable chlorophyl. Finally a series of chemical reaction were applied, especially that of concentrated sulphuric acid. The results still confirmed the identity of the two coloring-matters.

It is to be regretted that the scarcity of green Vorticellæ put for the present an end to these researches. In the mean time the facts ascertained suffice to put an end to the doctrine of the exclusively vegetable nature of chlorophyl. Even if it could be proved that the pigment of these Vorticellæ was ultimately derived from a vegetable source, the fundamental principle would remain unaffected. For the principle is that there are animals which by means of a pigment combined with their own living plasma, and not to be distinguished from the chlorophyl of plants, are able to assimilate under the stimulus of light exactly as do green vegetables.

It is not probable that the green *Vorticella* is the only animal which assimilates by means of its own chlorophyl. Years ago the author believes that he has met with specimens of *Cothurnia crystallina* of a diffused green color. It may also be asked whether the blue, brown, violet, and other pigments found in a diffused state in the ectoplasm of various infusoria are not genuine chromophyls, comparable with the xanthophyl, cyanophyl, rhodophyl, etc., of the algæ? Here is a wide field for research, and especially for the application of the bacteria method.

Is it not possible that in certain cases portions of animal plasma may have become differentiated "pseudo-algæ"—chromophyl-granules? Is it not judicious to pause before pronouncing every colored corpuscle, occurring in an animal, resembling a small alga and evolving oxygen in the light, to be a guest or inmate of vegetable origin?—*Journal of Science.*

A MATHEMATICAL PUZZLE.—"THE PACKER'S SECRET."

THE very ingenious French puzzle shown in the annexed cuts consists of a cardboard box containing twelve hard-wood counters or disks, which are scattered about loosely therein, as shown in the upper figure. The problem to be solved is how to arrange the pieces in the box (without the intervention of any foreign body) so that they shall remain perfectly immovable even when the box is shaken or turned upside down.

The mode of arranging the counters to effect this object constitutes "the packer's secret," and is as follows (see lower figure): First, piece No. 1 is put into the box, and Nos. 2, 3, 4, 5, 6, and 7 are arranged around it. Then the left hand is placed flat upon the pieces thus arranged, so as to keep them close together, and Nos. 8, 9, 10, 11, and 12 are inserted in such a way that they shall all bear against the sides of the box. Finally, the central piece, No. 1, is removed and placed in the remaining vacant space (No. 1 *bis*). The twelve pieces are thus rendered immovable, and the problem is solved.—*La Nature.*

THE SPIRIT OF CONTENT.

ALL permanent and real progress consists in the reconciliation between the two extremes of content and discontent, of satisfaction with the present and hopeful striving for the future. As a nation we are not in much danger of falling into the former extreme. Stolid and unenterprising people, thoroughly contented with themselves and their condition, and desiring neither the labor nor the excitement of striving for better things, are so rare with us, and so thoroughly despised, that they need but little comment. The other extreme is the one to which we are addicted; that of ignoring the present in our haste to provide for the future, of forgetting all causes of satisfaction in the many sources of dissatisfaction—of neglecting to *live* in the eagerness to get ready to live.

This is seen in every department of life. Youth, tip-toe with expectation of what is in store for riper years, pauses not to consider the special advantages or delights that belong to its own existence. It is the question "What shall I do, or be, or have, when I am a man?" not "What shall I do, or be, or have *now*?" that absorbs the thoughts of the youth, while the spring-time of life slips away, and its loveliest flowers are trodden under foot, unheeded and even unseen. The scholar who is adding to his stores of knowledge day by day seldom allows himself to rejoice in his mental possessions. He is reaching out so eagerly to grasp something more that he bestows no thought on what he has already gained, except to undervalue it. The more he learns the more he sees there is to learn, and while he dwells on that truth, he forgets the means by which it was revealed to him.

The artisan who has become skillful in his department, or the professional man who has risen to honor in his profession, rarely enjoys the knowledge of it, as would seem natural. The novice looks up to him with envy, and tries to picture to himself how supremely happy he must be, and how more than satisfied *he* would be could he arrive at such a position. He is mistaken on both points; and should he gain what he now so eagerly covets, he will look back with mild contempt upon his present convictions. So the man who is bent upon making money seldom stops to be glad that he

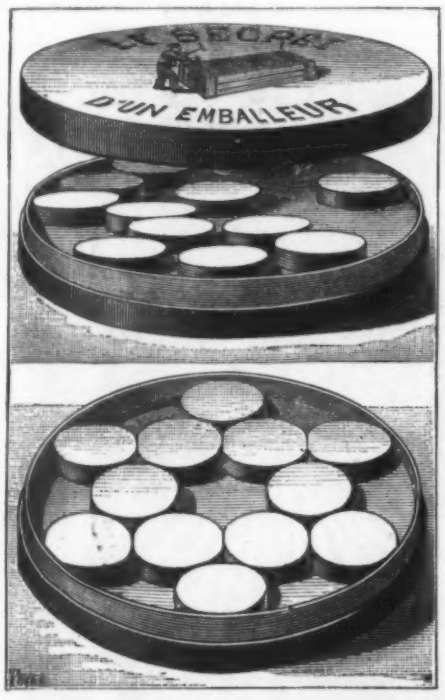


FIG. 1.—A MATHEMATICAL PUZZLE.—"THE PACKER'S SECRET."

has made so much in any sense of satisfaction. He rarely turns his attention to the fruits of his labor, or rejoices in the comforts that surround his family, the advantages he secures for his children, the opportunities he can offer to unknown merit or to struggling enterprise, the assistance he can render to needed reforms, or the help he can give to the feeble or oppressed. If he be of a generous disposition, he will attend to all these things; but, even then, how seldom does he dwell upon them in a spirit of calm and thankful contentment? They are to him rather like the wild flowers which the traveler may pluck and enjoy for a moment, but which he will drop at any time to observe a new turn in the road, or a guiding sign to direct his steps. Neither is the *spending* of money, however freely, attended with any great degree of satisfaction. We are all pretty sure that if we could but have a little more to spend on our houses, or our persons, or our luxuries, we should then be satisfied, but the time never comes, and it is quite certain it never will come through any such channel.

All this dissatisfaction with ourselves and our surroundings has its germ in what is right and natural. There is a "divine discontent" which lies at the root of all improvement, and without which we should stagnate. The indolence which craves nothing but quiet, the stupidity which sees nothing to hope or to work for, and the vanity which is

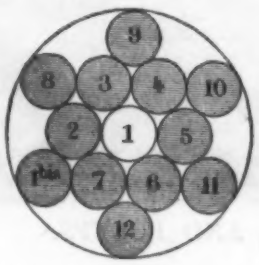


FIG. 2.—MODE OF ARRANGING THE PIECES.

self-satisfied through its ignorance of better things, are alike foes to happiness and clogs upon progress. Yet so also is the restless, unhappy spirit that sees no cause for satisfaction, that never pauses to review with pleasure the steps already trod, that lives always in an effort to grasp something which it never cares to keep, to pursue something which is let go as soon as touched. To lose sight of the end in the eager use of means, to forego results gained for the sake of results imagined, to live in a perpetual climb without admitting that we have climbed at all, to hope without ever recognizing "the substance of things hoped for," is a sort of slow suicide. It sacrifices life itself in the effort to improve it. Life passes away and slips from us while we are preparing to live. We lose its realities while dreaming of its possibilities. Ruskin well says: "The most helpful and sacred which can at present be done for humanity is to teach people (chiefly by example, as all best teaching must be done) not how to better themselves, but how to satisfy themselves. It is the curse of every evil nation and every evil creature to eat and *not* be satisfied. The words of blessing are that they shall eat and be satisfied.

And in order to teach men how to be satisfied it is necessary fully to understand the art and joy of humble life, this at present of all arts or sciences being the one most needing study."

Let us then unite these seeming opposites, and put each in its right place. As the farmer, while toiling unceasingly for future crops, yet gladly gathers in each harvest as it comes and rejoices in it, so let us, while relaxing no effort for future improvement, cultivate a spirit of content and satisfaction with actual results, and not only sow with diligence, but reap with gladness.—*Philadelphia Ledger.*

GLYCERINE IN BEER.

As is well known, glycerine is always produced simultaneously with alcohol when saccharine solutions are submitted to fermentation. According to Pasteur, 100 parts of cane sugar, corresponding with 105 parts of grape sugar, yield when completely fermented 51·11 per cent of alcohol and 3·16 per cent of glycerine. E. Borgmann has recently determined the ratio of glycerine to alcohol in different beers, and has found that the maximum is 5·947, and the minimum is 4·140 parts per 100 of alcohol, the mean being 4·803. A number of samples of English beer were examined, and although the alcoholic strength was much higher than Continental beers, the proportion of glycerine was found to be the same. A beer of average strength, containing say 5 per cent of alcohol, will therefore contain 0·24 per cent of glycerine.

A CATALOGUE containing brief notices of many important scientific papers heretofore published in the SUPPLEMENT, may be had gratis at this office.

THE
Scientific American Supplement.
PUBLISHED WEEKLY.
Terms of Subscription, $5 a Year.

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50, stitched in paper, or $3.50, bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents, and canvassers.

MUNN & CO., Publishers,
361 Broadway, New York, N. Y.

TABLE OF CONTENTS.

PAGE

I. ENGINEERING AND MECHANICS.—The Generation of Steam, and the Thermodynamic Problems Involved.—By WM. ANDERSON.—Practical difficulty connected with raising the temperature of a boiler.—The most efficient boiler.—Priming of boilers.—No marked improvement to be expected.... 7049
The Rondout Bridge.—With large engraving and 4 figures.... 7050
The French Ironclads L'Indomptable and Le Marceau.—With several engravings.... 7051
Improved Gas Engine.—3 figures.... 7052

II. TECHNOLOGY.—Improved Sponge Filters.—With two engravings.... 7052
Piefke's Improved Rapid Filter.—3 figures.... 7053
The Hyatt Filters.—With full description and three engravings.. 7054
Lead and Tin in Pottery and Glass.—Chemical purity not required.—Why adulterated articles cannot be used.... 7055
Ceramic Colors.... 7056
Manufacture of Charcoal.—Properties and uses of the same.—With engraving of charcoal pit.... 7056
New Useful Clearing Solutions for Gelatine Negatives.... 7056

III. ARCHITECTURE, ETC.—The Gardener's Cottage at Beirath Bury, Kells, England.—An engraving.... 7057
The Color Blue in Building Materials.—Causes of the color in different substances.... 7057
Roof Coverings.—By JOHN SLATER.—Conditions governing pitch of roof and materials used for the same.—Tile manufacture.—Metal coverings.—Effect of wind pressure.... 7059

IV. PHYSICS, ELECTRICITY, ETC.—Neveux's Vacuum Pump, which can be adjusted to Operate as either a Geissler or Sprengel Pump.—4 figures.... 7047
Sound-Mills, or Apparatus which Rotate under the Influence of Sound Waves.—6 figures.... 7059
Marcellac's Apparatus for Registering the Work of Piles.—1 engraving.... 7059
Michaelis's Photo-Thermometer.—2 figures.... 7060

V. NATURAL HISTORY.—Submarine Explorations.—Some of the marine animals found by the Talisman.—3 engravings.... 7060
On Animal Chlorophyl.... 7060

VI. MISCELLANEOUS.—A Mathematical Puzzle.—"The Packer's Secret."—3 engravings.... 7062
The Spirit of Content.—Real progress due to the reconciliation between content and discontent.... 7062

PATENTS.

In connection with the **Scientific American,** Messrs MUNN & Co. are Solicitors of American and Foreign Patents, have had 39 years' experience, and now have the largest establishment in the world. Patents are obtained on the best terms.

A special notice is made in the **Scientific American** of all Inventions patented through this Agency, with the name and residence of the Patentee. By the immense circulation thus given, public attention is directed to the merits of the new patent, and sales or introduction often easily effected.

Any person who has made a new discovery or invention can ascertain, free of charge, whether a patent can probably be obtained, by writing to MUNN & Co.

We also send our Hand Book about the Patent Laws, Patents, Caveats, Trade Marks, their costs, and how procured. Address

MUNN & CO., 361 Broadway, New York.
Branch Office, cor. F and 7th Sts., Washington, D. C.

Detroit Public Library